MODIFICATION OF THE ACOUSTIC AND CUTANEOUS BLINK REFLEXES BY FOCUSSED ATTENTION

By

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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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AUGUST 1989

Chairman: W. Keith Berg
Major Department: Psychology

The reflex blink has been used to study a wide range of psychological phenomena, among them selective attention. Previous research typically has found that when the sensory modality to which attention is directed and that of the eliciting stimulus match, the reflex is potentiated as compared with a condition in which they mismatch. A recent study found the opposite; when the sensory modalities of an acoustic eliciting stimulus and the focus of attention matched the reflex blink was smaller than in the mismatch condition. Four hypotheses were proposed to explain this seemingly anomalous finding and two experiments were carried out to test them. In both experiments, attention was manipulated by requiring subjects to discriminate the durations (long/short) of blink-eliciting bursts of white noise or periorbital airpuffs while the blink stimuli matching and not matching the task were presented. A

warning stimulus presented shortly before blink eliciting stimuli on 80% of trials was found to potentiate reflex blinks regardless of whether the blink stimulus was task-relevant or not. Additionally, the reflex amplitude for both stimulus types was further potentiated when subjects were judging airpuff stimuli. Thus, the apparently anomalous result of the earlier experiment was replicated, appearing as a relatively greater warning potentiation of responses to noise in the attend-puff condition. The response facilitation on warned trials results from subjects' generalized attention toward sensory inputs. The further potentiation produced by the puff task was inconsistent with hypotheses based on differential habituation, on puff-induced response sensitization, or on inhibition of the interference produced by responding during the task. Explanations of the facilitation by increased negative affect when judging airpuffs or greater task difficulty in that condition were also considered unlikely. The response potentiation produced by the judge-puff condition appears to reflect an intrinsic cognitive difference in processing task-relevant information from the cutaneous--as opposed to the auditory--sensory channel.

INTRODUCTION

The reflex blink may be elicited in human subjects by stimuli occurring in a number of sensory modalities. It may be elicited by acoustic stimulation as the most resilient part of the acoustic startle response (Landis & Hunt, 1939), by visual stimuli, and by periorbital cutaneous stimuli (Shahani & Young, 1973). In producing the blink, the various sensory inputs converge in the ponto-medullary reticular formation (Rimpel, Geyer, & Hopf, 1982) before following a common final path from the facial nucleus via the facial nerve to the muscle, orbicularis oculi, which is used in blinking.

The reflex blink has been used as a dependent measure in investigations of a wide range of topics, including conditioning (e.g., Cook, Hodes, & Lang, 1986; Greenwald, Hamm, Bradley, & Lang, 1988; Spence, 1966; Spence & Platt, 1966), affect (Bradley, Cuthbert, & Lang, 1989; Cook et al., 1986; Lang, Bradley, & Cuthbert, 1989), perceptual thresholds and sensory processing (Haerich, Woods, & Berg, 1989; Woods & Haerich, 1989; Hoffman, 1984), inter alia. The primary neural structures involved in the cutaneous blink reflex have been identified (Hiraoka & Shimamura, 1977; Ongerboer de Visser, 1983; Ongerboer de Visser &

Kuypers, 1978) as have those in the acoustic startle response (Davis, 1984). Elicited by stimulation in multiple sensory channels, consisting of known neural circuitry, and useful in investigations of a number of psychologically interesting topics, the blink reflex has shown itself a power research tool.

Noting the differing effects of various interstimulus intervals (ISIs) when the reflex eliciting stimulus is preceded by a weak lead stimulus, Graham (1975) suggested that the reflex might be modifiable by selective attention. Subsequent research suggested that, when compared with blinks elicited without attention being manipulated (i.e. without warning), the response was potentiated if attention was directed toward the modality in which the startling stimulus was presented (Bohlin & Graham, 1977; Ison & Ashkenazi, 1980) and was inhibited if attention was directed toward another sensory modality (Silverstein, Graham, & Bohlin, 1980).

In the work cited above, comparisons were made between reflexes evoked after a warning stimulus cued subjects attention toward a certain sensory modality. Since the blink response may be elicited by stimuli in multiple sensory channels, the response system also allows the assessment of attentional effects in a complete factorial design. For one factor, attentional direction, attention is directed toward or away from the sensory channels comprising the other factor. Such a design,

using visual and acoustic stimuli, has produced both the facilitatory and inhibitory attention effects described above using both infant subjects (Anthony & Graham, 1983) and adults (Anthony & Graham, 1985).

Previous Research

A brief review of earlier studies which elicited reflex blinking while directing attention both toward and away from the eliciting stimulus will be helpful in contextualizing the current research.

Bohlin and Graham (1977) asked subjects to discriminate the durations (long/short) of startling acoustic (tones, noise) stimuli. For both types of eliciting stimuli, blinks were facilitated on warned as compared with unwarned control trials. Similar results were reported by Bohlin, Graham, Silverstein, and Hackley (1981) who elicited reflex blinks with bursts of white noise on both warned and unwarned trials in a series of experiments. The critical stimulus manipulation was the modality of the lead stimulus; for all experiments, each block of seven trials included five trials warned by a vibrotactile lead stimulus, one unwarned trial, and one trial on which the lead stimulus was either acoustic or visual. In one experiment, the critical acoustic or visual lead stimuli appeared without prior announcement and thus were novel stimuli. Blinks elicited during the orienting induced by these novel lead stimuli were

facilitated in comparison with the blinks on the just-as-frequent unwarned trials. In another experiment, subjects were instructed to judge the duration of the eliciting stimulus only on those, infrequent, trials which used acoustic or visual lead stimuli. As in the earlier study (Bohlin & Graham, 1977), blinks were larger on the critical, judgment trials than either the unwarned trials or the non-judgment trials. A final experiment in which subjects were told only to "attend" to the infrequent lead stimulus, but performed no task, found no differences in blink amplitude between trial types. Two results of importance are indicated by these studies. First, when subjects are attending to a task-relevant stimulus responses are facilitated. Secondly, a similar facilitation may be produced during orienting when subjects direct their attention to sensory inputs in general.

Silverstein et al. (1981) directed subjects to judge the duration of an electrotactile (forearm) stimulus while simultaneously presenting a blink-eliciting acoustic stimulus. Blinks elicited on warned trials were inhibited with respect to blinks elicited without warning. These data indicated that inhibition resulted when blinks were elicited by a stimulus in a sensory modality which did not match that to which attention was directed.

Anthony and Graham, with both infant (1983) and adult subjects (1985), demonstrated both facilitatory and

inhibitory effects of attention. In each experiment the subjects were divided into two groups and presented with a relatively engaging (that is, interesting) foreground stimulus, or one not so engaging (dull). These foreground stimuli were intended to direct the attention of the subject toward a particular sensory modality, the interesting foregrounds being more effective than dull foregrounds. For one group these two types of foreground stimuli were visual (e.g., for infants, color slides of smiling faces versus blank color slides), and for the other acoustic foregrounds were used (e.g., music box tunes versus a 1000 Hz tone). Four seconds after onset of the foreground stimulus, a startle response was elicited by a stimulus which either matched or did not match that of the foreground stimulus. When the modality of the startle eliciting stimulus matched that of the foreground, the reflexes were potentiated, more so when attention was engaged by an interesting foreground. Further, when the foreground and startle stimuli were mismatched, with attention being actively directed toward a different modality (an interesting foreground), the reflex amplitude was inhibited as compared to reflexes elicited after either of the dull foreground stimuli. Reflex latencies were also facilitated when foreground stimuli and eliciting stimuli matched. Comparisons with blinks elicited on unwarned, or no foreground, trials were not made.

Typically, research on attention and the reflex blink has used acoustic stimuli to elicit the response. Hackley and Graham (1983) used both acoustic and airpuff stimuli in an attempt to extend to the cutaneous modality the results of previous work in blink modification by manipulating selective attention. In the first experiment, a startle-eliciting acoustic stimulus was paired with a non-startling airpuff which was simultaneously delivered to the third digit of the left hand. Subjects were required to judge the durations of either acoustic or airpuff stimuli (short or long) and were instructed to concentrate on the task stimulus and ignore the other, distracting stimulus. After 36 trials, subjects required to attend acoustic and ignore airpuff stimuli continued for an additional 36 trials with the attend and ignore stimuli reversed. This ordering was counter balanced across subjects. The second experiment, conducted with a different group of subjects, was identical to the first except that the reflex eliciting stimulus was a periorbital airpuff which was paired with a non-startling acoustic stimulus. For both experiments the magnitude of the blink and its latency were facilitated when attention was directed toward the modality of the startling stimulus as compared to an attend-away condition. However, the changes in blink magnitude after a cutaneous stimulus (Experiment 2) did not reach statistical significance.

A further attempt to elicit significant attentional effects with cutaneous stimuli was made by Haerich (1988). Stimuli, binaurally presented noise bursts and periorbital airpuffs, were presented individually so that, on a given trial, subjects could receive either stimulus type. As in the Hackley and Graham study (1983), a duration discrimination task was used to direct subjects' attention toward or away from a given stimulus modality. The task-relevant stimulus always occurred twice as frequently as the irrelevant stimulus. In this experiment, cutaneously elicited responding was driven unwittingly to ceiling because of the potency of the airpuff stimulus. Acoustically elicited responses did vary, but in a direction opposite that observed by Graham and her colleagues (Anthony & Graham, 1983, 1985; Hackley & Graham, 1983). That is, noise induced blinks elicited while subjects were judging noise durations (i.e. the attend-toward condition) were inhibited relative to those elicited in the judge-puff (attend-away) condition. The focus of the present research is to examine reasons for the unexpected finding of the Haerich (1988) study.

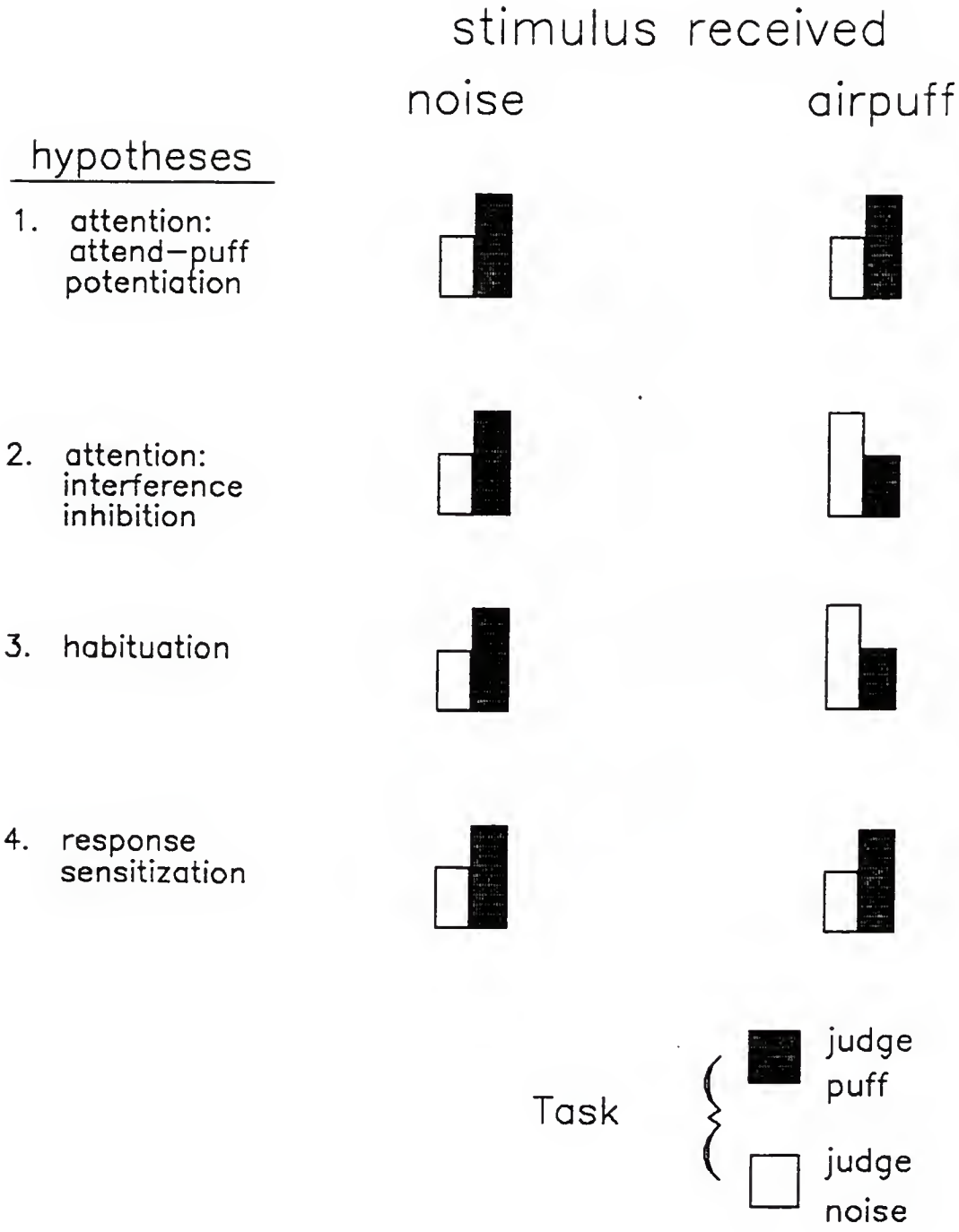
Hypothetical Prospectus

A number of explanations may be advanced for the effects observed by Haerich (1988) on acoustically elicited blinks. First, the paradigm, which required subjects to make a duration judgement, may have enhanced

generalized orienting by the subjects which could, in turn, have produced larger responses under a more difficult task condition (Bohlin & Graham, 1977; Bohlin et al., 1981). Subject reports that the airpuff discriminations took more effort suggest that subjects instructed to attend to airpuffs may have shown a stronger orienting response than when attending to noise (a suggestion supported by a (non-significant) greater heart rate deceleration just prior to the eliciting stimulus in the attend-puff condition). In this way, responses to acoustic stimuli in the attend airpuff condition would be relatively larger than in the attend-noise condition. Apparently, response differences to airpuff stimuli were not observed by Haerich because the intensity of the stimuli was so great as to produce ceiling effects. Were the ceiling effects avoided, this hypothesis would predict that the puff elicited responses would have been influenced in the same direction as the noise elicited ones; that is, attend-puff blinks would have been enhanced relative to attend-noise blinks. (See Figure 1 for a summary of predictions by this and the following hypotheses.) This hypothesis does not propose an effect specific to a single eliciting modality, but rather, one which results from the focussing of attention and occurs regardless of the eliciting modality.

A second, alternative, hypothesis for the Haerich (1988) results which does predict (eliciting) modality

Figure 1. Hypothesis Predictions. Predicted response patterns for each of the four hypotheses. The predictions apply for Experiments I and Experiment II, group one.


stimulus received
noise
airpuff
hypotheses
1. attention: attend–puff potentiation
2. attention: interference inhibition
3. habituation
4. response sensitization
Task
judge puff
judge noise

specific effects suggests that the physical expression of the blink reflex could interfere with the required duration judgement regardless of the modality of the stimulation, and as a result, the subject's optimal task performance would require minimizing that interference by inhibiting the blink. The locus of this interference inhibition is activity in a modality specific, central pathway. This hypothesis predicts effects associated with selective attention which are apparently contrary to those observed by previous researchers (e.g.,Anthony & Graham 1983, 1985; Hackley & Graham, 1983). The conflict may be clarified by taking into account differences between the experimental contexts faced by subjects in the Haerich (1988) study and by subjects in the earlier Hackley and Graham work. When, for a given subject, a blink-eliciting stimulus from only one modality is used occurring on all trials (as was the case in Hackley & Graham, 1983), interference effects from the reflex blink should be equivalent under both attend-toward and attend-away conditions, since the task must be carried out in both cases. This constant influence would allow the independent facilitatory effects of attention/stimulus modality matching to appear. When the blink stimulus may be presented in either of two modalities on a given trial, as in Haerich, 1988, subjects will continue to reduce interference effects from responses elicited by the task-relevant stimulus. However, when a blink stimulus is

presented that is not task-relevant, no reduction of interference is required, since there is no task to be carried out. Thus, in this situation, inhibition effects would not be distributed across stimuli and attentional conditions in an equivalent manner; rather, this hypothesis predicts that subjects could effectively reduce interference by inhibiting responses in the task-relevant stimulus alone, thus producing the reported results. This hypothesis differs from the first in its prediction that, were ceiling effects on puff-elicited blinks avoided, the responses would show a modality specific effect of attentional condition with blinks in the attend-puff condition being inhibited relative to the attend-noise condition (figure 1, hypothesis 2).

In addition to these two hypotheses which were advanced by Haerich (1988), a third alternative suggests that the results of Haerich (1988) reflect differential habituation. Since the task-relevant stimulus occurred more frequently, greater habituation would be expected leading to the results seen for acoustically elicited responses. This effect was not observed in the cutaneously elicited responses because 1) the intensity used was so great as to produce relatively little habituation for the number of presentations made, or, 2) the cutaneous blink reflex is expressed in a pathway which is generally less affected by habituation. Assuming habituation occurs, the habituation hypothesis would predict (paralleling

hypothesis #2 above) that, were effects observed on puff-elicited blinks, responses in the attend-puff condition would be smaller than in the attend-noise condition (figure 1, hypothesis 3).

A final hypothesis suggests that it is possible that the reported results reflect differences in response sensitization produced by the probability of occurrence for each stimulus. In each block of six trials, the task-relevant stimulus was presented four times as compared with two for the task-irrelevant stimulus. Airpuff stimuli, in general, elicit blinks of larger absolute magnitude than those elicited by noise. It follows, then, that the greater amplitudes observed for acoustically elicited blinks in the attend-puff condition may reflect a generalized response set for greater responding, a sensitization that extended to the noise induced responses. This effect was produced by the potent airpuff stimuli which occurred twice as frequently in the attend-puff condition. In this case, were ceiling effects on cutaneously elicited blinks avoided, effects would follow those predicted by the first hypothesis above with amplitudes of puff-elicited blinks in the attend-puff condition being greater than in the attend-noise condition (figure 1, hypothesis 4). Further, since the response sensitization is (hypothetically) induced by the greater frequency of airpuff stimuli, the observed pattern of

results could be manipulated by changing the ratio of stimulus presentation.

Four hypotheses, then, are proposed to explain the results of Haerich (1988). Two of them, the habituation and the response sensitization hypotheses (figure 1, hypotheses 3 and 4), predict that the pattern of results will follow the frequency with which the various stimuli are presented. The other two predict attention related effects that should be independent of frequency of presentation, general potentiation while judging airpuffs on the one hand, or inhibition of responding to task-relevant stimuli on the other. In order to investigate possible effects of selective attending further and to understand better the results reported by Haerich (1988), two experiments were conducted which evaluate these hypotheses.

Since the results of Haerich (1988) were in the opposite direction from those reported by previous studies which have manipulated attention, the first task is to establish the reliability of the effect. Experiment 1--partial results of which were reported by Haerich & Berg (1988)--attempts to replicate the results of Haerich (1988) using a lower intensity airpuff.

It may first of all be noticed from the above hypotheses, that, if the effects could be demonstrated in more than the auditory modality, much information could be obtained. The first and the fourth hypotheses predict

that for puff-elicited blinks, the attend-puff condition would produce potentiated responses relative to the attend-noise condition. The second and third hypotheses predict the opposite, that for puff-elicited blinks, the attend-puff condition would produce inhibited responses relative to the attend-noise condition. (Figure 1) Therefore, one primary goal of these experiments was to devise conditions more conducive to demonstrating possible attentional influences in responding to cutaneous stimuli. To accomplish this, Experiment I used an airpuff stimulus of lower intensity that did Haerich (1988) and the intensity was decreased further for Experiment II. Experiment II also attempted to foster any attentional effects which previously lay beyond the experimental limb. Attention was enhanced by 1) decreasing the preparation interval (from 4 s to 2 s) and 2) increasing the difficulty of the stimulus-duration-discrimination task (i.e. manipulating the stimulus durations).

It may also be noticed that the hypotheses proposed above differ in their prediction as to the sensitivity of the response to the stimulus presentation frequency. Hypotheses three and four suggest that presentation frequency is a major factor in producing the observed results. Therefore, Experiment II manipulated the presentation frequency of the stimuli across task

conditions. This was designed to separate the effects of response sensitization and habituation from those of orienting and selective attention.

EXPERIMENT I

This experiment was designed as a replication of Haerich (1988) to find out if the effect of attentional condition on noise elicited reflex blinks was reliable. In several earlier studies (e. g., Hackley & Graham, 1983), when the modality to which attention was directed was also that in which the eliciting stimulus was delivered, responses were potentiated compared to the condition in which the modality of attention mismatched the stimulus. The results of Haerich (1988) were in the opposite direction; responses were smaller in the matched condition than in the mismatched. Since, given the context of the previous research, this result was unexpected and unprecedented, it was decided that a replication was in order to establish the reliability of the effect.

It should also be recalled that in the previous study (Haerich, 1988) the effect of attentional condition was found only for acoustically elicited blinks. Blinks elicited by airpuff showed no effect of attentional focus, apparently because the intensity of the stimulus drove responding to the ceiling. One of two changes in procedure from that of Haerich (1988) was to decrease the

intensity of the airpuff stimulus from 155 mm Hg (flow = 302 cc/s), to 60 mm Hg (flow = 151 cc/s). This change was made with the aim of lowering responses from ceiling, thus allowing any effects of selective attention to appear.

The second change in procedure was the inclusion of unwarned control trials. The earlier studies of the reflex blink and attention (Bohlin & Graham, 1977; Bohlin et al., 1981; Silverstein et al., 1981) utilized only a single reflex eliciting stimulus and used unwarned trials as the primary comparison. Those studies utilizing two eliciting stimuli (Anthony & Graham, 1983, 1985; Hackley & Graham, 1983; Haerich, 1988) compared attend-toward with specific attend away conditions. Since the effect observed by Haerich (1988)--acoustically elicited blinks in the attend-noise condition were of lesser amplitude than those in the attend-puff condition--had not been reported previously, the question of the response's relationship to unwarned blinks was open and it was decided the such trials should be included in the replication.

Method

The methods used in Experiment I are a replication of those used by Haerich (1988) save two exceptions noted above. A detailed exposition is included at this point because the methods of Experiment II will be, by and large, similar.

Subjects

Subjects were 23 students enrolled in a General Psychology course who received course credit for their participation. Data from two of these were not included in analyses because equipment failure led to the loss of portions of their data. The remaining 21 subjects (females = 9) ranged in age from 17 to 23 years (mean = 18.7 years).

Stimuli

Three different stimuli were used, a warning light, and two types of startle eliciting stimuli, noise bursts and airpuffs.

The warning light, a red LED, was used to inform subjects of the beginning of a trial, allowing subjects to relax between trials and thus avoid extended vigilance effects.

The white noise bursts were generated by a Grason-Stadler Model 455C noise generator and presented binaurally. Sound levels were calibrated with a Quest Audiometer Calibration System, Model 215-4512AM, at 95 dB(A) at each ear. Noise bursts were of two durations, 50 ms and 100 ms, both with 2.5 ms rise/fall times matching those used by Haerich (1988).

Airpuffs, the other stimulus used to elicit the blink reflex, were regulated by a KGM Model 1208 regulator to 60 mm Hg with a flow rate of 151 cc/s, a level reduced from the 155 mm Hg (flow = 302 cc/s) used by Haerich (1988). A

solenoid (Skinner Electric Valves, Series VAO) gated air flow from the regulator through a plastic tube to a nozzle (inside diameter = 4 mm) attached to the headpiece which also held the earphones. The nozzle was adjusted so that the orifice was 1 cm from the skin and directed one half centimeter temporally to the outer canthus of the left orbit. The durations of the airpuff stimuli, like the noise bursts, were 50 ms and 100 ms.

All noise bursts and airpuffs used during the experiment were capable of eliciting a reflex blink.

Data Collection and Analysis

An IBM PC which controlled the timing and order of trial and stimulus presentation was also used to collect electrophysiological data.

Electromyographic (EMG) activity from orbicularis oculi was recorded with two miniature Sensor Medics Ag/AgCl surface electrodes attached with adhesive collars below the left eye as described by Fridlund & Cacioppo (1986). EMG was recorded for 250 ms beginning 25 ms prior to the onset of the startling stimulus. For airpuffs, the length of the plastic tubing, the electric valve, and the AC switch controlling it introduced a 26 ms delay following the computer signal to initiate the stimulus; cutaneous reflex latencies were corrected for this 26 ms delay prior to analysis.

The signal was amplified by a Coulbourn Instruments S75-01 Hi-Gain Bioamplifier (band pass filtering of 8 to

250 Hz) and integrated by a Contour Following Integrator (Coulbourn Instruments, S76-01) at an empirically determined time constant of 114 ms. The integrated signal was fed through a Beckman polygraph (Type 411) where additional but negligible filtering (22 Hz lowpass) was provided by a Beckman type-9806A coupler before being digitized on line by a Tecmar LabMaster unit in the IBM PC sampling at 1000 Hz with 12 bit sampling resolution. These data were stored on disk for off-line analysis.

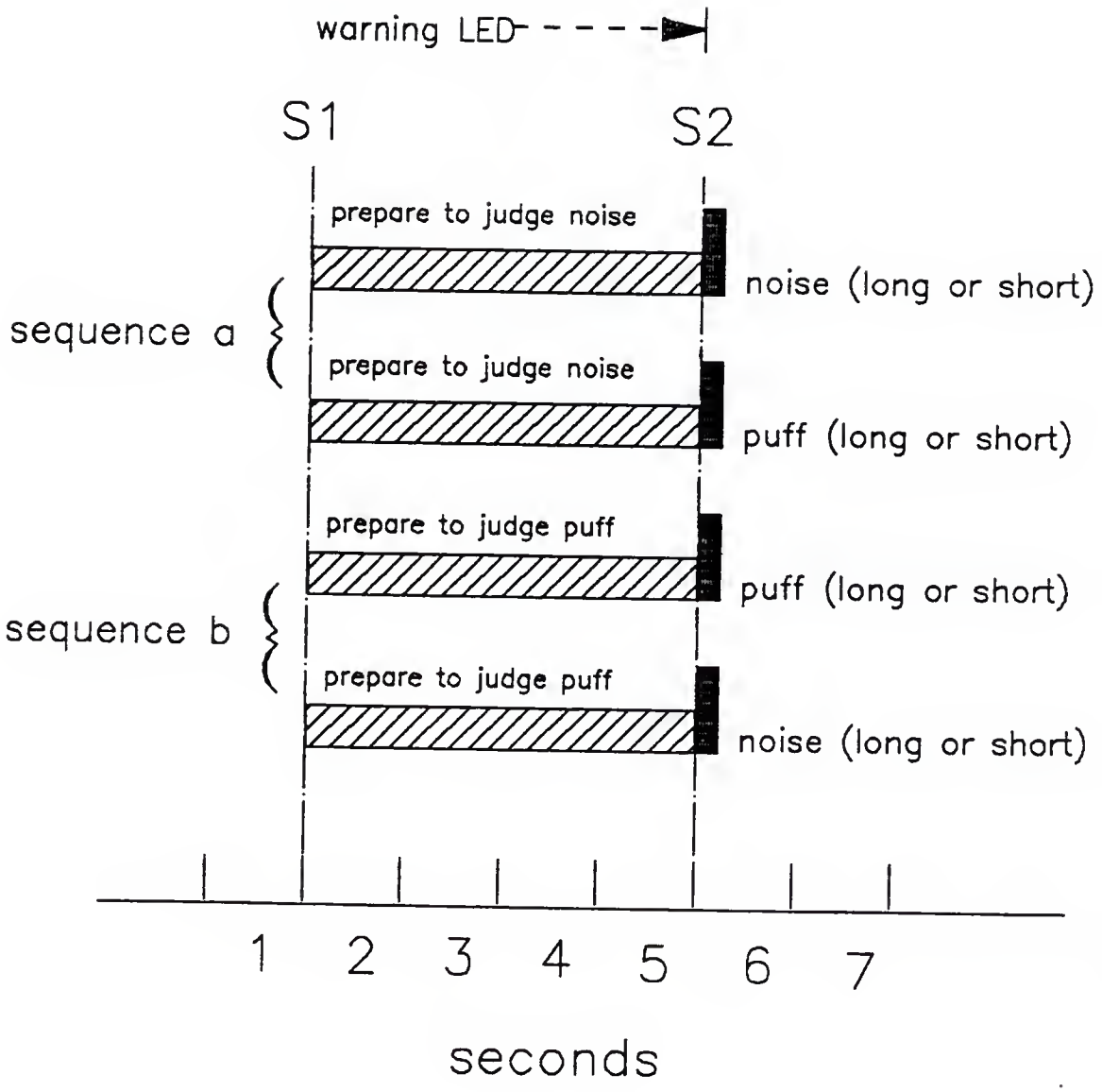
Data used in analyses of reflex probability, latency, and amplitude were obtained by off-line scoring of digitized, integrated EMG records. Previous research (Haerich, 1988) indicated that responding was unaffected by the stimulus duration manipulation. These data were, therefore, combined for analysis. An automatic scoring program was written which searched each trial for blink onset, defined as the point, within a window of 20 - 120 ms after stimulus onset, at which the signal began a deviation in the direction of a blink of at least 40 a-d units within 3 ms. Peak amplitude was scored relative to the pre-response baseline as the maximum deviation within a window the bounds of which were the point of response onset and 160 ms after stimulus onset. The pre-response baseline was calculated as the mean value for the 20 ms prior to the response onset. If no blink onset or obvious peak could be determined, that trial was not included in latency and amplitude averages, and was scored as a 'No

Blink' trial. Blink probability was defined as the number of blink trials divided by the sum of the no-blink plus blink trials for each condition within subjects. Trials in which the EMG indicated that the muscles were already active at stimulus onset, subsequently obscuring blink onset, were not included in the probability computation, nor in other response measures. Values for blink latency and amplitude were averaged across trials for each condition within subjects; these averages and the blink probability scores were used in statistical analyses.

Heart rate data were collected for ten seconds beginning two seconds prior to onset of the warning light, or the equivalent interval on unwarned trials. Since the first and last seconds of data (considered seconds number zero and nine respectively, see figure 2) included partial cardiac cycles of indeterminate length, valid data were available from the second prior to onset of the warning light, throughout the four seconds of the warning interval, and for three seconds after onset of the blink-eliciting stimulus.

Electrodes were attached to the arms and left leg in a Lead II arrangement. Inter-R-wave intervals were computed to the nearest millisecond and stored on disk for off line conversion to second by second heart rate. Average second by second heart rate was calculated within subjects for each condition for use in statistical analyses. These data were collected to provide a

Figure 2. Trial Events. Summary of events occurring during each trial. During each sequence of trials, subjects judged durations only for one type of stimulus, but could receive stimuli of either type. For Experiment II, the ISI was decreased by two seconds.


warning LED
S1
S2
prepare to judge noise
noise (long or short)
sequence a
prepare to judge noise
puff (long or short)
prepare to judge puff
puff (long or short)
sequence b
prepare to judge puff
noise (long or short)
1
2
3
4
5
6
7
seconds

physiological indication that subjects were attending during trials (Bohlin & Graham, 1977; Graham et al., 1975)

Procedure

After obtaining informed consent from subjects and attaching the five electrodes, the subjects were seated in an IAC sound attenuating chamber. The headpiece with the earphones and airpuff nozzle was donned and adjusted so that it was comfortable and so that the nozzle was directed as described above. Subjects were instructed to sit as still as possible during the experiment and to fixate the warning light located .75 m directly in front of the subject, and were told that this light would come on at the beginning of each trial. Subjects were then told that they would be receiving a number of stimuli, some of which would be bursts of noise while others were puffs of air, that each type of stimulus would either be short or long in duration, and that their task was to judge the stimulus with respect to these duration categories. All subjects were then presented with an example of short and long duration stimuli of each type (noise and airpuff). The subjects were instructed to verbally report their judgements using an FM two-way radio device (Maxon Model 49-SA) attached to the headset.

Finally subjects were told that, although both noise and puff stimuli would occur, they should concentrate and report durations for only the airpuffs (10 subjects) or noise (11 subjects). They were instructed to "be ready

for," to " concentrate on," and to "pay special attention to" the specified stimulus type and to report their discrimination decisions only for these stimuli. They were told to ignore the other stimulus which occurred and that they need not report judgments for them. After the first sequence of trials, these instructions were reversed and subjects were asked to judge the second stimulus type, ignoring the first. A speeded response was not requested and feedback was not given.

The purpose of the duration discrimination task was to focus subjects' attention on one or the other sensory modality during the trial. It was expected that above chance performance on this task could be used in conjunction with the heart rate data as indicative of the focusing of attention by the subjects. A heart rate deceleration reaching nadir just prior to the blink stimulus would be indicative of orienting and the focusing of attention on the task in general (Bohlin & Graham, 1977; Graham & Clifton, 1966; Graham, Putnam, and Leavitt, 1975; Sokolov, 1969), and a high score on the judgement task would be indicative of the direction of the focus toward the modality of the task relevant stimulus.

The experiment consisted of two sequences of 30 trials each. For each sequence, warned trials were arranged into four blocks of six trials, four trials of each were of the to-be-judged, or task-relevant type, two of the task-irrelevant type. Short and long duration

stimuli were included equally in each block. A total of six unwarned (i.e. warning light omitted) trials were inserted, evenly dispersed among the warned trials such that every five trials contained four warned trials and one unwarned trial. Three of the six unwarned trials were noise; three were airpuff.

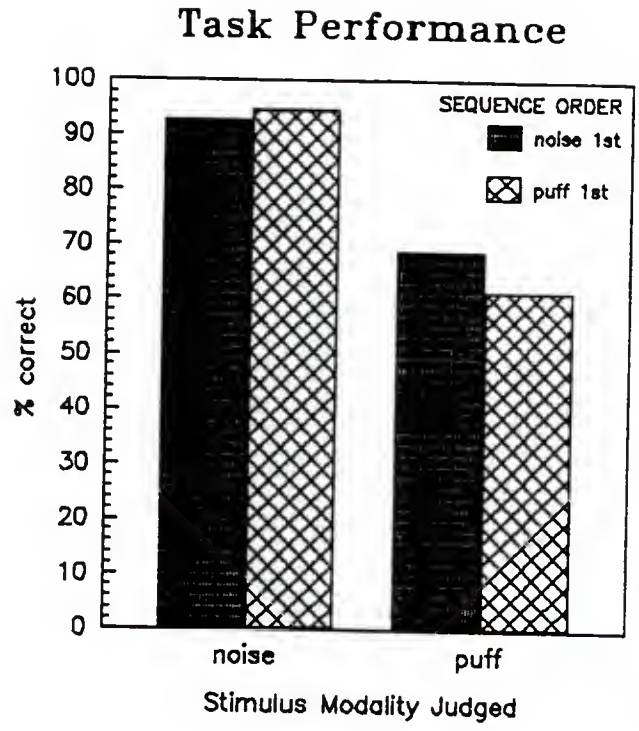
The procession of events within each trial was constant (see figure 2). Four seconds after onset of the warning light the startling stimulus, either an airpuff or a noise burst, was presented. The eight seconds of heart rate retained for analysis began one second prior to onset of the warning light. EMG was recorded for 250 ms beginning 25 ms prior to onset of the startling stimulus. Unwarned trials were different from warned trials only in that the warning light was omitted. The inter-trial interval varied between 15 and 25 seconds (mean = 20 s).

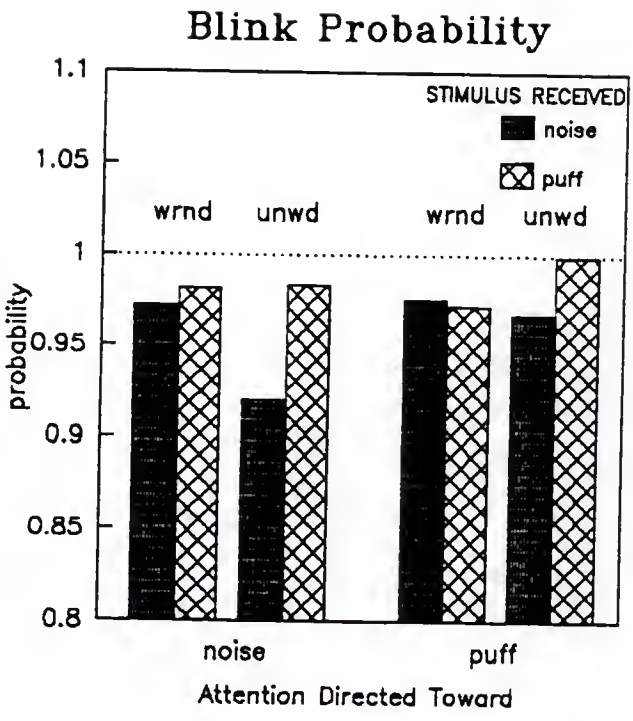
Results

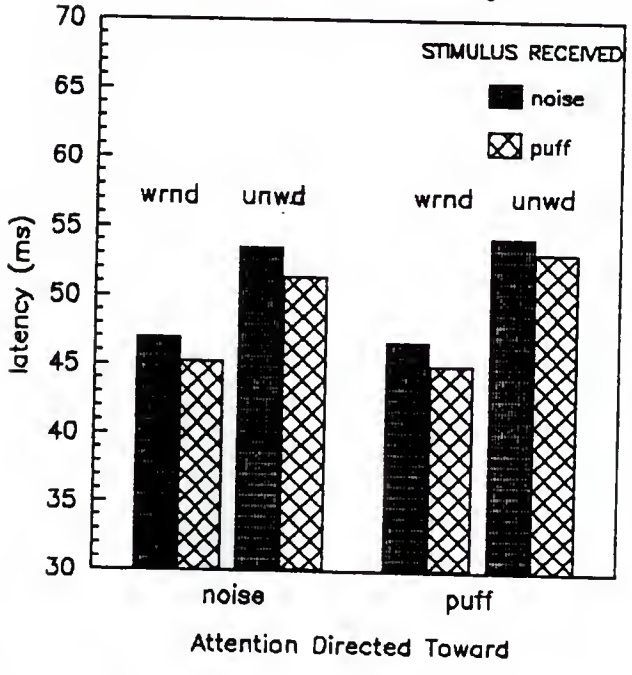
Task Performance

As may be seen from figure 3, which shows the performance results, no difference was found between those subjects who judged noise first and those who judged airpuffs first (F's < 1). The subjects did very well in judging the durations of noise stimuli; however, they did significantly less well in discriminating long and short airpuffs (F (1/20) = 43.51, p < .001). Nevertheless, chi-square analyses indicate

Figure 3. Blink Response: Experiment I.
a) Task Performance (top, left). Percentage of correct discriminations of each stimulus type presented for each sequence order. b) Blink Probability (top, right). Probability of a reflex blink during warned and unwarned trials for both stimulus types. c) Blink Latency (bottom, left). Reflex latency in each condition. Latencies on unwarned trials are greater than on warned. d) Blink Amplitude (bottom, right). Reflex amplitude expressed as the percentage of the mean reflex amplitude for each stimulus modality. On warned trials, blinks to noise stimuli are greater when subjects are instructed to judge airpuffs as compared to judging noise.


Task Performance
% correct
100
90
80
70
60
50
40
30
20
10
0
SEQUENCE ORDER
noise 1st
puff 1st
noise
puff
Stimulus Modality Judged


Blink Probability
probability
1.1
1.05
1
0.95
0.9
0.85
0.8
STIMULUS RECEIVED
noise
puff
wrnd
unwd
wrnd
unwd
noise
puff
Attention Directed Toward


Blink Latency
latency (ms)
70
65
60
55
50
45
40
35
30
STIMULUS RECEIVED
noise
puff
wrnd
unwd
wrnd
unwd
noise
puff
Attention Directed Toward

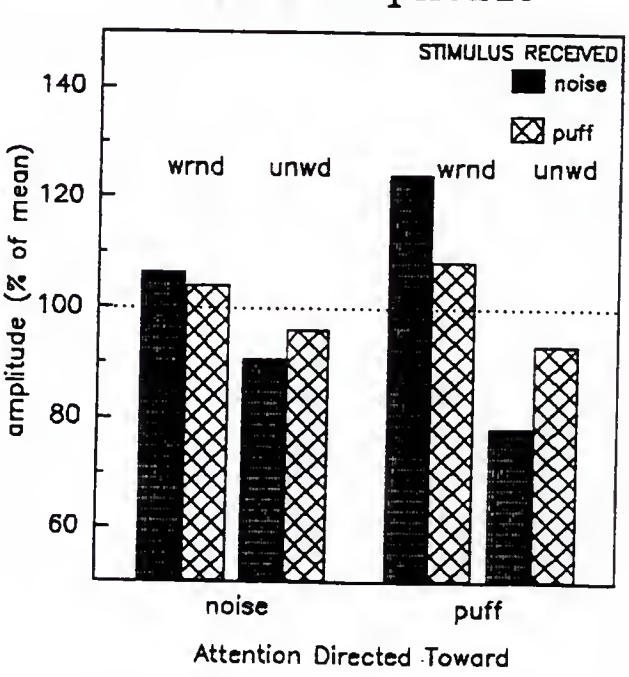
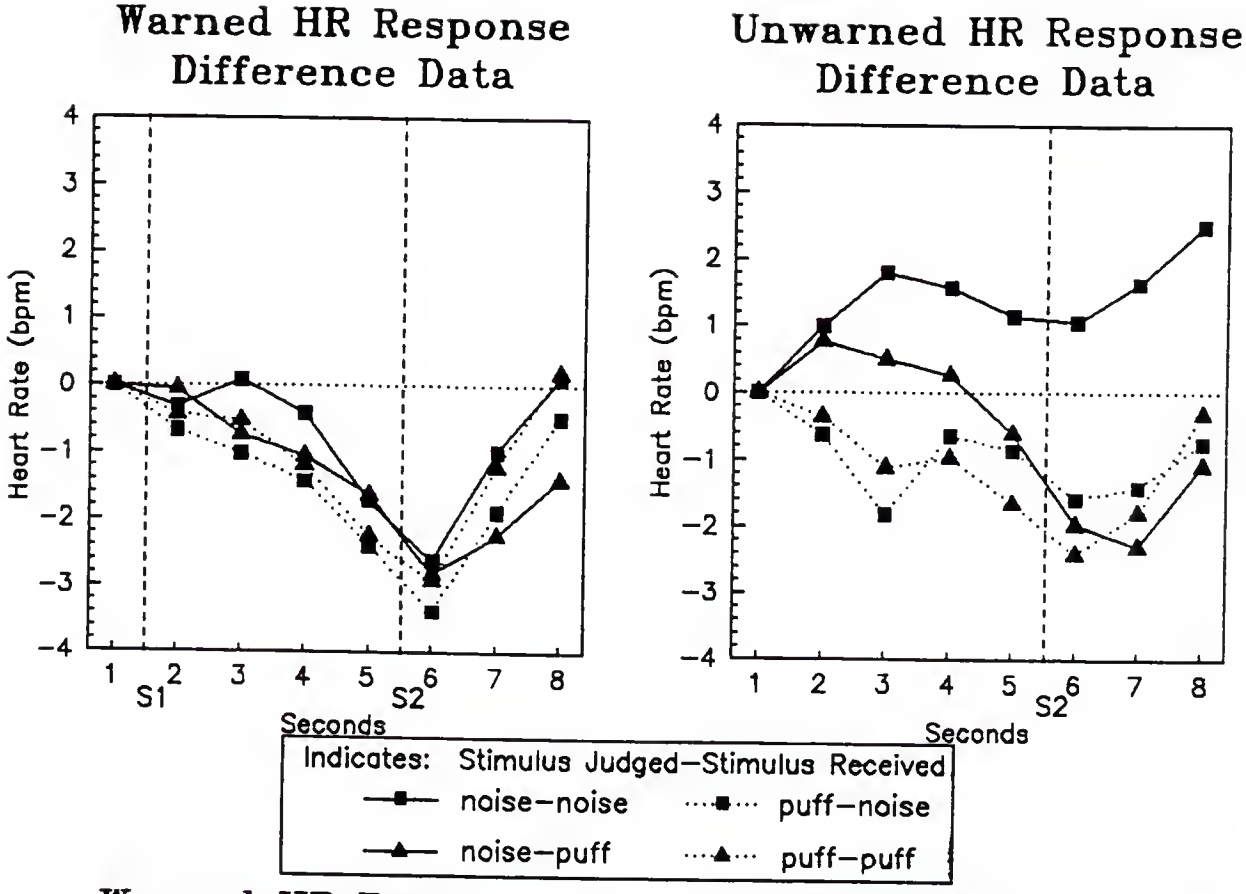
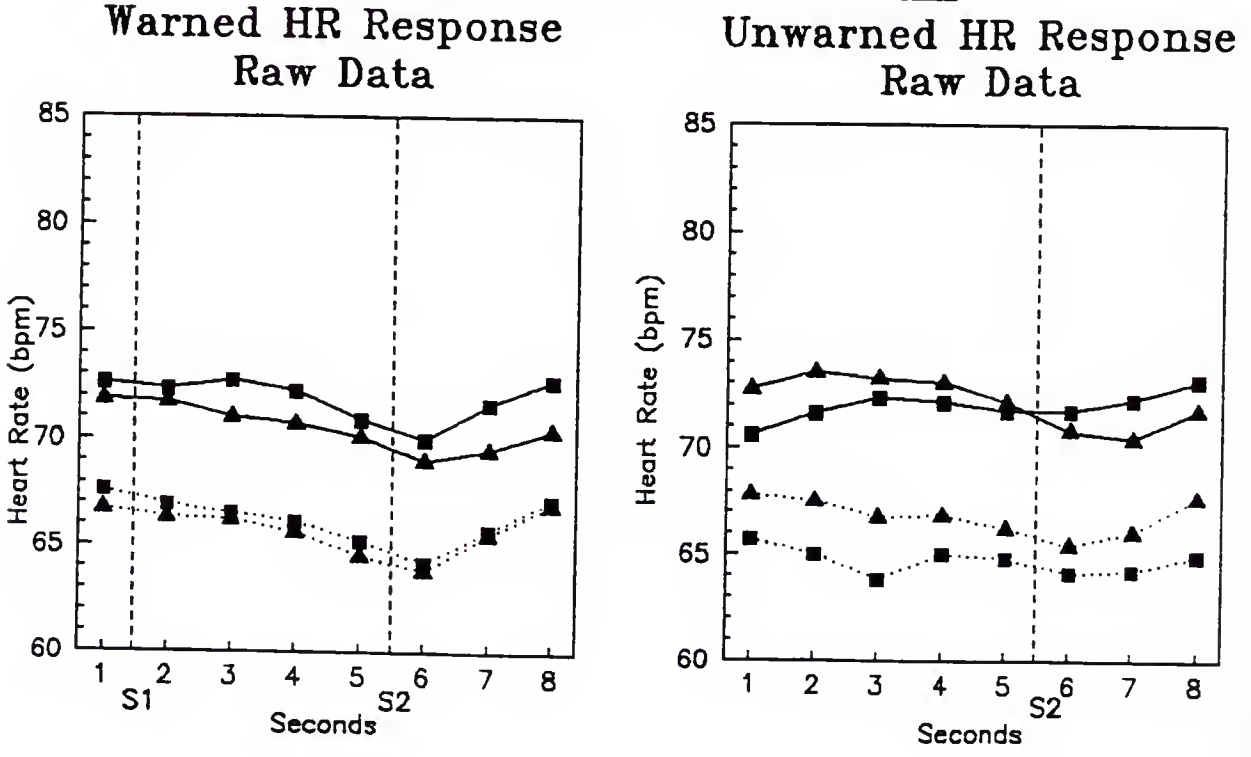

Blink Amplitude
amplitude (% of mean)
140
120
100
80
60
STIMULUS RECEIVED
noise
puff
wrnd
unwd
wrnd
unwd
noise
puff
Attention Directed Toward

Figure 4. Heart Rate: Experiment I. Average heart rate responses for warned (left) and unwarned (right) trials. Data are expressed in both raw form (bottom) and difference scores (top) calculated relative to the second prior S1 onset. Data points represent the average heart rate across an entire second and thus should be considered as representing the mid-point, in time, of the second. For this reason, stimulus occurrences are midway between data points.


Warned HR Response
Difference Data
Unwarned HR Response
Difference Data
Heart Rate (bpm)
Seconds
S1
S2
Indicates: Stimulus Judged—Stimulus Received
noise—noise
puff—noise
noise—puff
puff—puff


Warned HR Response
Raw Data
Unwarned HR Response
Raw Data
Heart Rate (bpm)
Seconds
S1
S2

performance on both stimuli was significantly greater than chance (chi squares (1) = 70.56 and 9.61, p's < .01 for noise and puff respectively). These results differ from those of Haerich (1988) in which task performance on the two types of stimuli was approximately equal, being 90% and 87% correct for noise and airpuff judgments, respectively. Apparently the decreased intensity of the airpuffs used in the present experiment greatly increased the difficulty of the puff discrimination task.

Heart Rate

Warned and unwarned second by second heart rate responses are shown in figure 4. It appears that, on warned trials, heart rate responded similarly for each condition, decelerating after the warning stimulus, reaching a nadir just subsequent to the onset of S2, and accelerating across the next three seconds. Unwarned trials, while showing an acceleration after the eliciting stimulus, produced no evidence of consistent heart rate trends prior to S2.

Repeated measures analysis of variance (ANOVA) of seconds one to six reveal a significant effect of warning (F (1/20) = 8.09, p < .01) and a significant warning X linear seconds interaction (F (1/20) = 10.67, p < .01). Heart rate decelerated subsequent to the onset of the warning stimulus, responding similarly in each of the warned conditions. On unwarned trials no consistent trends across seconds were found prior to S2 onset. An

overall effect of attentional condition also reached significance (F (1/20) = 5.89, $p < .05$). This appears to be due to the tendency for heart rate in the attend-noise condition to be greater than that in the attend-puff condition, especially in unwarned trials. Inspection of raw heart rate data (see figure 4, bottom panels) indicates that baseline heart rate in the attend-noise was condition was 5 beats per minute greater than in the attend-puff condition, an observation which would appear to be significant by the intra-ocular trauma test, as well.

Heart rate accelerated across seconds six to eight, the seconds subsequent to the reflex eliciting stimulus. Analysis of this acceleration revealed a significant linear trend (F (1/20) = 25.97, $p < .001$). In addition, the effect of warning also reached significance (F (1/20) = 9.44, $p < .01$), apparently due to accelerations on warned trials consistently starting from a lower level than unwarned ones. No other main effects or interactions achieved significance.

The persistent cardiac deceleration prior to a warned S2 is indicative of a signal orienting response (Graham & Clifton, 1966; Sokolov, 1969; cf. also Lacey & Lacey, 1970). When taken together with the results of the duration judgements, there is strong converging evidence that subjects were focusing attention on (at least) the task relevant stimulus as instructed.

Blink Responses

Probability. Blink probability was uniformly high, greater than 0.9, as can be seen in figure 3. Analysis of variance detected no significant main effects or interactions.

Latency. An effect of warning is immediately apparent upon inspection of the data. This is confirmed by ANOVA (F (1/20) = 45.61, $p < .001$) indicating that providing a warning stimulus greatly reduced response latency for both stimulus modalities. The direction of the means also suggests a stimulus effect in which the response to noise occurs with greater latency than the response to airpuff; however, the main effect of stimulus was not significant (F (1/20) = 1.33, $p > .10$). Except the effect of warning, no main effects or interactions reached significance.

This lack of attention direction effect on response latency fails to replicate the results of Haerich (1988) which found that latencies to acoustic stimuli when attending to noise were greater than when attending to puff.

Amplitude. In order to make responses more readily comparable across subjects and stimulus modalities, responses were normalized by calculating the mean response to each stimulus type for each subject, then expressing the data by condition in terms of percentage of that mean. Raw scores are included in Appendix A.

The main effect of attention condition failed to reach significance. Nevertheless, these normalized data reveal a pattern of responding which mimicked that of Haerich (1988). Warned, acoustically elicited blinks when attending to cutaneous stimuli were larger than when attending to noise.

An ANOVA did reveal a significant main effect of warning (F (1/20) = 19.62, $p < .001$) indicating that responding after a warning was potentiated as compared with responding on unwarned trials. Blinks elicited by noise stimuli were, on the whole, more sensitive to effects of warning (Warning X Stimulus interaction, F (1/20) = 5.84, $p<.05$).

Although the main effect of attention direction did not reach significance, when subjects were attending to airpuffs, the effect of warning was potentiated (Attention X Warning interaction, F (1/20) = 5.17, $p < .05$). The effect of warning occurred for both acoustically and cutaneously elicited blinks.

Follow-up analyses conducted on responses from warned trials alone did reveal a significant effect of attention at a marginal confidence level (F (1/20) = 3.19, $p = .07$). The interaction with stimulus did not achieve significance ($p > .10$).

Discussion

One primary purpose of this experiment was to replicate the task condition effect of Haerich (1988). Strong evidence from the performance and heart rate data demonstrate that subjects were attending to the stimuli. At the same time, there was a significant Attention X Warning interaction for blink amplitude in which the potentiating effect of warning was greater while subjects were attending to airpuffs than while attending to noise. This effect was confirmed by direct follow-up analyses. Taken together, these data suggest that the effect observed by Haerich (1988) was indeed replicated; acoustically elicited blinks were potentiated during the attend-puff condition relative to the attend-noise condition.

The Attention X Warning interaction, in the absence of a three-way interaction with stimulus, also suggests that cutaneously elicited responses might also be sensitive to the task manipulation. These responses were also potentiated in the attend-puff condition. Since the other goal of this experiment was to produce conditions conducive to the demonstrating influences on airpuff-elicited responses by lowering the airpuff intensity, it would appear that both goals were achieved. As such it is appropriate at this point to discuss the current results in terms of the four hypotheses proposed above.

The interference inhibition hypothesis (figure 1, hypothesis 2) would not explain these data. This hypothesis, which posited that selective attention inhibits responding to task-relevant stimuli predicts a reduction in response amplitude for puff-elicited blinks in the attend-puff condition. The analysis indicates that the opposite occurred. In the same way, the habituation hypothesis (figure 1, hypothesis 3) also runs into trouble as it would predict that airpuff-elicited blinks would be of smaller amplitude in the attend-puff condition due to their greater frequency of presentation. Again, the analysis suggests the opposite was the case.

The response sensitization hypothesis (figure 1, hypothesis 4) does receive partial support from these data. This hypothesis suggested that a generalized response sensitization is produced by a combination of the intensity of the airpuff stimulus and its relative frequency in the attend-puff condition. Responding to warned stimuli of both types is potentiated in the attend-puff condition. However, this hypothesis would also predict that responding to unwarned stimuli, as well, would be potentiated. Rather, the opposite appears to have been the case, with unwarned responses accounting for a smaller percentage of the mean in the attend-puff condition than in the attend-noise condition. This is not a peculiarity of the normalization procedure since the

same effect was evident in the raw scores (cf. Appendix A).

The attend-puff potentiation hypothesis, the one that proposed some attentional mechanism, perhaps akin to orienting, was involved in the airpuff judgment trials (figure 1, hypothesis 1) would also predict greater blink amplitudes for warned responses to both types of stimuli. Unlike the response sensitization hypothesis, this hypothesis does not predict that responding to unwarned stimuli would be potentiated as well. It would, therefore, seem that, of the four hypotheses proposed above, the one which best predicts the observed data is that of increased orienting during the attend-puff condition.

It was also suggested by hypothesis one, above, that the enhanced orienting during the attend-puff task could have been induced by the greater difficulty of the duration discrimination task for airpuffs than for noise. Such a suggestion would predict that this difficulty might be reflected in the task performance data and/or in the heart rate data. In the Haerich, 1988, study, there was no apparent difference in task performance; subjects performed at about a 90% correct level for both stimuli. However, in the current experiment, the intensity of the airpuff stimulus was decreased. This decrease in stimulus intensity might also be expected to lead to greater difficulty in discrimination. In fact, with the decrease

in stimulus intensity, performance on airpuff discrimination dropped to 65%, suggesting that such an increase in difficulty did occur.

Haerich (1988) suggested that airpuff discrimination was more difficult, based, not only on subjects reports that such judgments required more "effort," but also on a (non-significantly) greater heart rate deceleration in the attend-puff condition just prior to S2 as compared with the attend noise condition. The raw heart rate data in the current experiment provided further support as the attend-puff condition produced baseline heart rates consistently below that of the attend-noise condition. Such a generalized decrease in heart rate might be expected if subjects were attending to exogenous environmental stimuli with greater cognitive effort (Lacey, 1967; Lacey & Lacey, 1974).

While the results of Experiment I seem consonant with a mechanism which potentiates responding while subjects discriminate airpuffs, these data cannot entirely preclude contributing effects of response sensitization. These effects would be sensitive to manipulation of stimulus presentation frequency. This will be tested explicitly in Experiment II.

The absolute amplitude of the effects on cutaneously elicited blink was small. Additional interpretive comfort

would be derived if these cutaneous effects could be reproduced and magnified. Steps towards this end will also be taken in Experiment II.

EXPERIMENT II

The primary purpose of Experiment II was to assess the effect of varying the frequency with which task-relevant stimuli were presented.

Both Experiment I and Haerich (1988) presented stimuli with a relevant-irrelevant ratio of two to one. This confounds possible effects of attending to the task-relevant stimulus modality with effects cause by the relatively greater frequency of that stimulus' presentation. In order to test for possible effects of presentation frequency, the three groups of subjects in Experiment II were presented with stimuli with relevant-irrelevant ratios of two to one, one to two, and one to one.

The attend-puff potentiation and interference inhibition hypotheses (figure 1, numbers 1 and 2) predict that manipulating the frequency with which task-relevant stimuli are presented will have a negligible effect on responding. Whether task-relevant stimuli are more or less frequent than irrelevant stimuli, the attend-puff potentiation hypothesis predicts that responding to both stimulus types will be facilitated when airpuffs are task-relevant. Similarly, the interference inhibition

hypothesis predicts that, for example, noise-elicited blinks will be smaller while judging noise than while judging puffs independent of the frequency with which those stimuli are presented.

In contrast, the habituation and response sensitization hypotheses (figure 1, numbers 3 and 4) predict that the responding is largely under the control of the relative frequency with which the different stimuli are presented. The habituation hypothesis predicts that presenting one stimulus more frequently than the other will produce relatively greater habituation and, thus, reduced responding to that stimulus. This hypothesis predicts that this response reduction occurs whether or not the stimulus is task-relevant.

The response sensitization hypothesis also predicts that manipulating the ratio of task-relevant and irrelevant stimuli will affect the pattern of responding. For this hypothesis, it is the frequency of airpuff presentation, rather than stimulus frequency in general, that is the critical variable. Whichever trial sequence presents puff stimuli more often will produce facilitated responding to both stimulus types.

It should also be noted that the attend-puff potentiation and response sensitization hypotheses on the one hand and the interference inhibition and habituation hypotheses on the other also may be differentiated (see figure 1). For the former two hypotheses, responding in

each attention condition varies together for both stimulus types; that is, when responding elicited in one stimulus modality is potentiated in a given attention condition, the responding elicited in the other stimulus modality will be too. For the latter two hypotheses, the patterns of responding to each attention condition vary in opposite directions for the two stimulus types, that is, when the response elicited by one stimulus is potentiated in a given attention direction, the response to the other stimulus will be potentiated by the other attention direction.

It follows that producing clear and distinct effects by both stimulus types will maximize the expository power of the results. In Experiment I, the intensity of airpuff stimuli were decreased in an effort to lower responding away from ceiling. The results suggested that factors involved in attending to airpuff stimuli may measurably affect responding to that stimulus. Still, the absolute size of the difference between attention conditions for cutaneous blinks was small. In an effort to magnify any effects of selective attention, especially on puff-elicited blinks, the intensity of airpuff stimuli was further decreased.

The temporal parameters of the paradigm were also altered to facilitate the attentional manipulation. It is possible that with the four second ISI used in the previous experiment, attentional resources may have begun

to dissipate before S2 presentation, especially with increasing numbers of trials (F. K. Graham, personal communication, 21 October 1988); therefore, the ISI was decreased to two seconds in order to allow subjects more effectively to devote their attentional resources to the task while continuing to provide a sufficiently large interval for measuring cardiac deceleration (Bohlin & Kjellberg, 1979). Also, stimulus durations were modified to equate more accurately task difficulty for the two stimulus types.

The attend-puff potentiation hypothesis posits that an attentional mechanism, perhaps akin to orienting, is involved in the judge-puff trials. Task difficulty is one factor which has been suggested as being important to this mechanism. In Experiment I, task difficulty was operationally defined in terms of performance on the discrimination task. In order, therefore, to measure subjective difficulty more accurately, a brief rating-questionnaire was devised in which subjects could rate their perceptions of the task. Besides task difficulty, evaluations of interestingness and pleasantness were also gathered to provide information relevant to possible affective influences of the tasks (P. J. Lang, personal communication, 5 June 1989).

Method

Subjects

Subjects were 48 students enrolled in a General Psychology course who received course credit for their participation.

Stimuli

In order to lower the blink amplitude further from ceiling, and thereby facilitate any attention related effects on cutaneously-elicited responding, the intensity of the airpuff stimulus (controlled by an AIRCO 400 Series low pressure regulator) was reduced to 55 mm Hg. Additional restriction was applied to the regulator outflow reducing the flow rate to 29.2 cc/sec. The intensity of the noise bursts was also decreased to 93 dB(A). These values were chosen as they have been found to represent a point of subjective equality for perceived intensity in a cross-modal matching task (Woods & Haerich, 1989).

Stimulus durations were 100 and 110 ms for noise bursts and 50 and 110 ms for airpuffs. These durations were chosen as pilot testing (N = 4) indicated that they produced equivalent performance at a 60% to 70% level in the discrimination task. This change from Experiment I was made in order to increase the overall attentional effort required of subjects by the task. This change also equates task difficulty across stimuli as reflected in

performance, as the results of Experiment I may have been due (in part) to a greater difficulty in airpuff discriminations.

Subjects were divided into three groups the critical difference between which was the ratio of task-relevant to task-irrelevant stimulus presentations within a given trial sequence. For group one the relevant-irrelevant ratio was two to one as it was in Experiment I and Haerich (1988). In group two the ratio was one to one, and in group three one to two. Other aspects of stimulus presentation including the frequency of unwarned stimuli was the same as Experiment I. The groups in the current experiment were run sequentially during a period of seven weeks with the data from subjects in group one collected first and group two last.

A rating-questionnaire was used to measure subjects' perceptions of the discrimination task on three scales: difficulty, interestingness, and pleasantness. The questionnaire consisted of a printed line for each scale, and in the case of difficulty judgements was labeled at one end "very difficult" and at the other "very simple." Labelling for the interestingness and pleasantness scales was equivalent. After each sequence subjects were asked to indicate on each of the three continuous scales their rating of the task by locating marks through the lines to indicate the degree of difficulty, etc., which they perceived associated with the task; the experimenter was

not in the room with the subjects while the ratings were made. After the session ended, the position of these lines was measured to the nearest millimeter and expressed as a proportion of the length of the entire line such that a score of 1.0 indicates the maximum rating of difficulty, interestingness, and pleasantness, and a score of 0 indicates the minimum.

The questionnaire was a procedure added after subject testing was partially complete. Because of the sequence in which groups were tested (see above), complete data are available only for group two, data for 9 of 16 subjects are available for group three, and none is available for group one. While this precludes adequate evaluation of group, or stimulus presentation frequency, effects on these measures of task motivation, it still provides important information regarding task and stimulus influences.

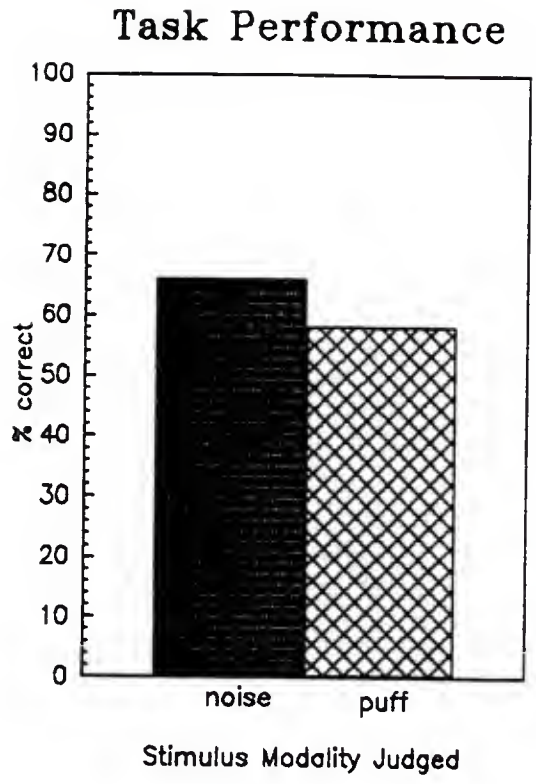
All other procedures, materials, and methods were as described in Experiment I.

Results

Task Performance

Across all groups, subjects were able to discriminate correctly noise and airpuff durations on 66.1 % and 58.3 % of trials respectively (figure 5). While performance on the acoustic discrimination task fell well within the target range of 60% to 70%, performance on airpuff

Figure 5. Blink Response: Experiment II.
a) Task Performance (top, left). Percentage of correct discriminations of each stimulus type presented for each sequence order. b) Blink Probability (top, right). Probability of a reflex blink during warned and unwarned trials for both stimulus types. c) Blink Latency (bottom, left). Reflex latency in each condition. Latencies on unwarned trials are greater than on warned. d) Blink Amplitude (bottom, right). Reflex amplitude expressed as the percentage of the mean reflex amplitude for each stimulus modality. On warned trials, blinks to both noise and puff stimuli are greater when subjects are instructed to judge airpuffs as compared to judging noise.


Task Performance
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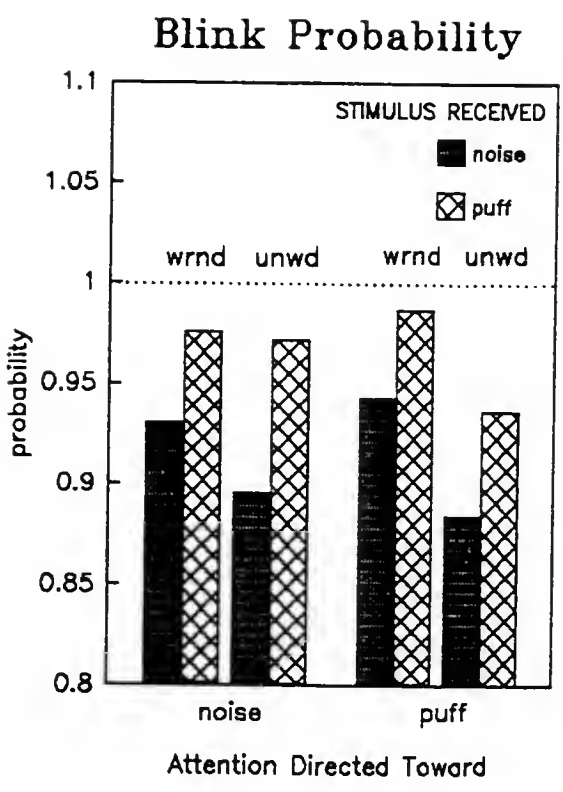
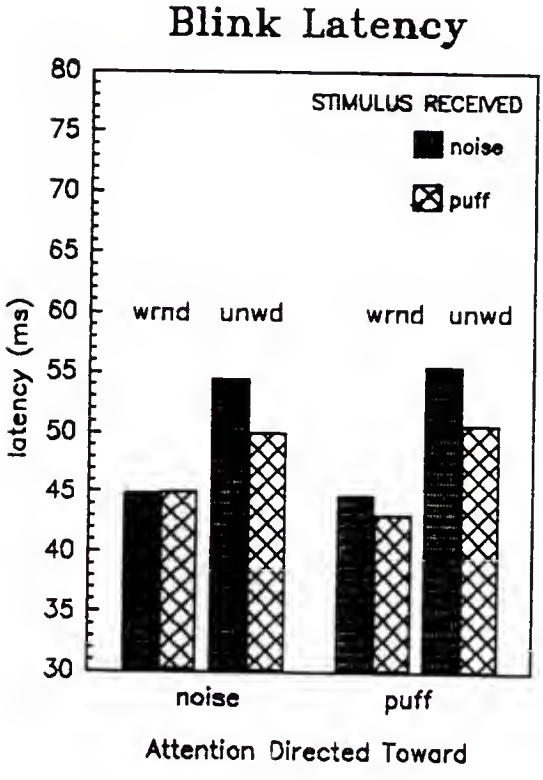
80
70
60
50
40
30
20
10
0
% correct
noise
puff
Stimulus Modality Judged


Blink Probability
1.1
1.05
1
0.95
0.9
0.85
0.8
probability
STIMULUS RECEIVED
noise
puff
wrnd unwd wrnd unwd
noise
puff
Attention Directed Toward


Blink Latency
80
75
70
65
60
55
50
45
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35
30
latency (ms)
STIMULUS RECEIVED
noise
puff
wrnd unwd wrnd unwd
noise
puff
Attention Directed Toward

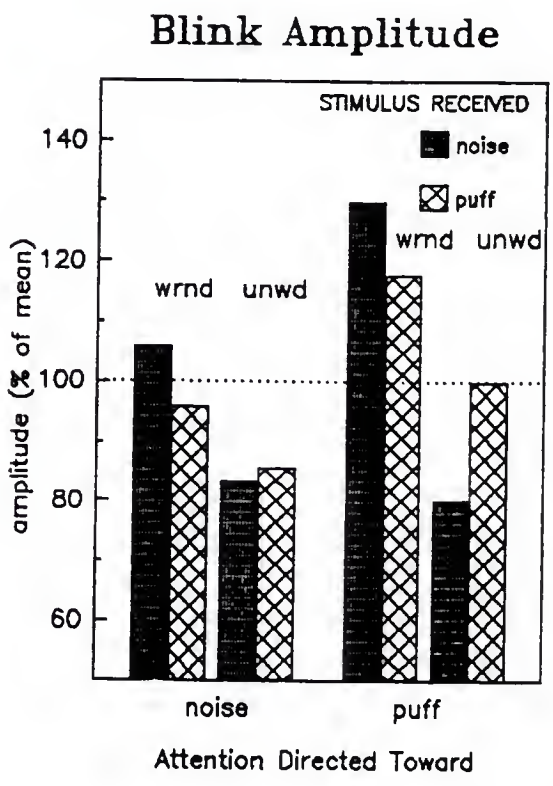
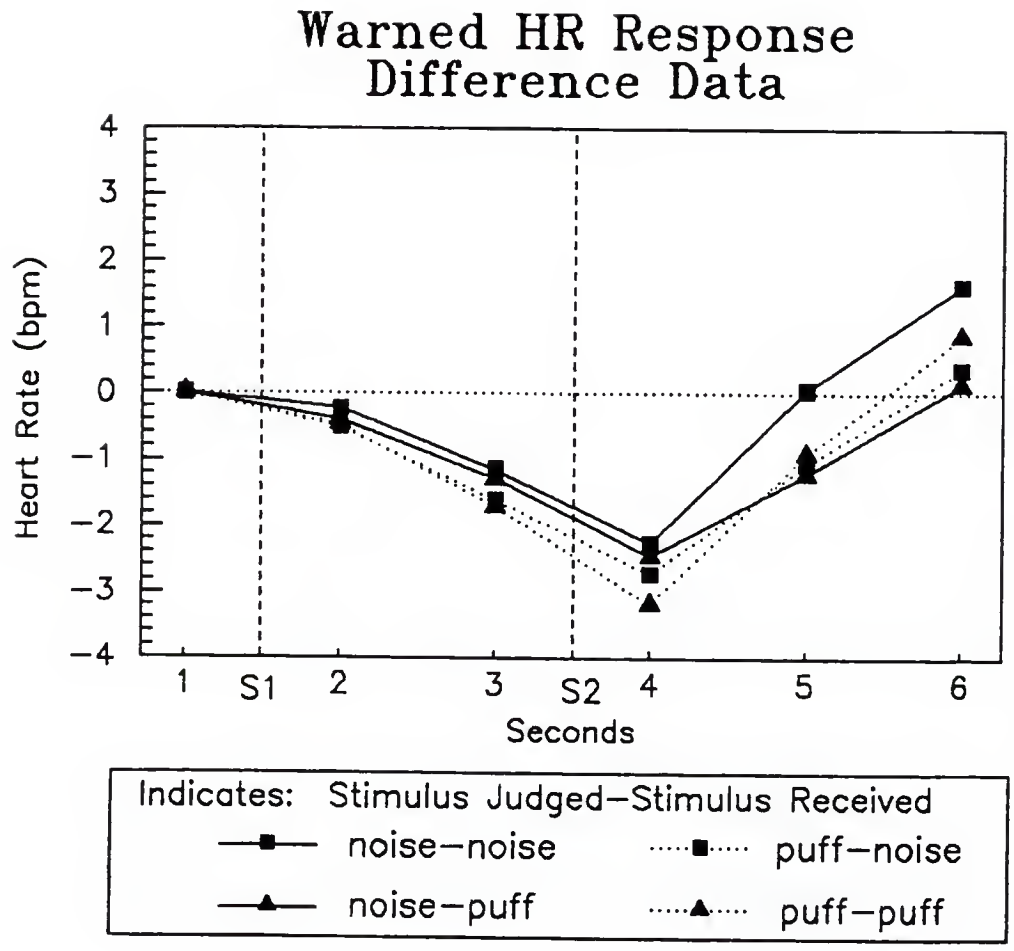
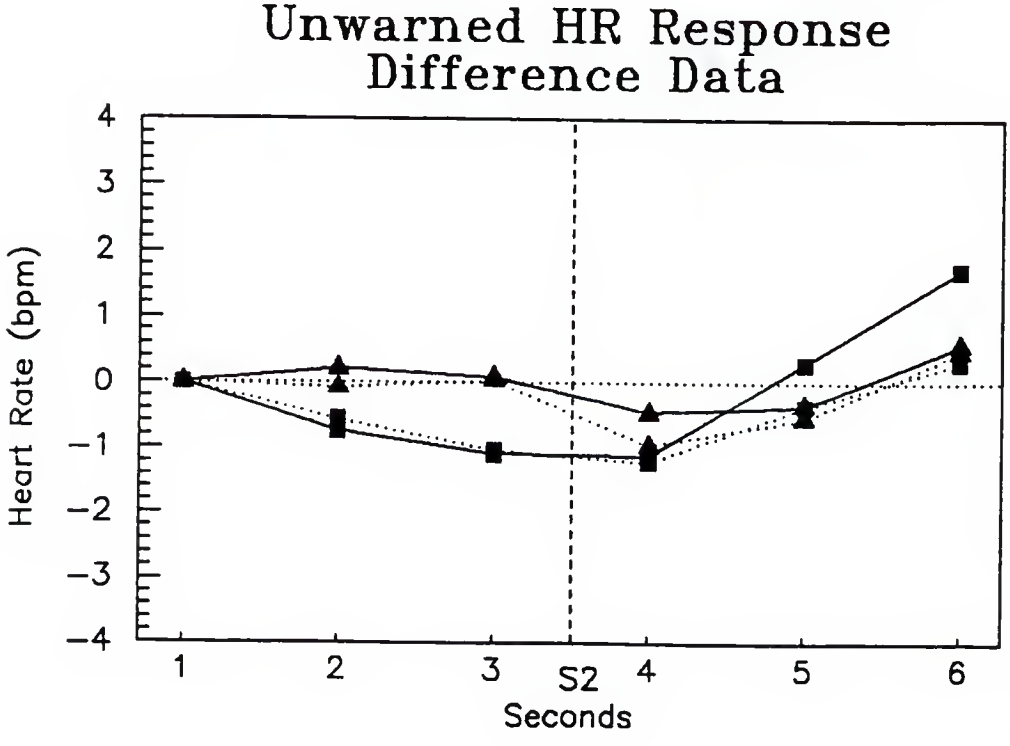

Blink Amplitude
140
120
100
80
60
amplitude (% of mean)
STIMULUS RECEIVED
noise
puff
wrnd unwd
wrnd unwd
noise
puff
Attention Directed Toward

Figure 6. Heart Rate: Experiment II. Average heart rate responses for warned (top) and unwarned (bottom) trials. Data are expressed as difference scores (top) calculated relative to the second prior S1 onset. Data points represent the average heart rate across an entire second and thus should be considered as representing the mid-point, in time, of the second. For this reason, stimulus occurrences are midway between data points.


Warned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
S1
2
3
S2
4
5
6
Seconds
Indicates: Stimulus Judged−Stimulus Received
noise−noise
puff−noise
noise−puff
puff−puff


Unwarned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
2
3
S2
4
5
6
Seconds

discrimination did not. In addition, chi-square analyses indicate that only acoustic discrimination was significantly above chance (noise: chi square (1) = 10.2, $p < .05$; puff: chi square (1) = 2.56, $p > .05$). Considering the performance of the individual groups it may be seen that when the ratio of relevant to irrelevant stimuli is two to one or one to one, performance on airpuff discriminations is 63.5% and 63.7% respectively, together significantly greater than chance (chi square (1) = 6.76, $p < .05$). However, when the frequency of task-relevant stimuli is decreased in the one to two ratio, performance drops to 47.7% correct. Performance by the same groups on noise discriminations was 61.2% , 70.0%, and 67.0% respectively. An ANOVA indicates a significant Stimulus X Group interaction (F (2/45) = 4.55, $p < .025$).

Heart Rate

Considering the heart rate responses (figure 6), responding appears to have been similar to that in Experiment I. Heart rate decelerates across the interstimulus interval, but only when the warning, S1, stimulus is presented. Subsequent to the reflex eliciting stimulus, an acceleration occurs whether or not a warning stimulus had been presented.

Analysis of the deceleration across seconds one through four reveals a significant linear trend (F (1/45) = 44.34, $p < .001$) across the interval. That the deceleration occurs for warned trials only is indicated by

a significant effect of warning (F (1/45) = 6.83, p < .025) and a Warning X Linear Seconds interaction (F (1/45) = 13.07, p < .001). Neither the main effect of group, nor any of its interactions achieved significance.

The analysis of cardiac responding after the reflex stimulus is more complicated. The acceleration across seconds four to six appears as a significant linear trend across seconds (F (1/45) = 92.60, p < .001). No other main effects or trends achieved significance. Neither the main effect of group, nor any of its interactions achieved significance.

A number of interactions with linear seconds appear to result from differences in slope and differences in the points at which the accelerations begin, particularly on unwarned trials. These include Attention X Stimulus X Linear Seconds (F (1/45) = 9.61, p < .01), Stimulus X Linear Seconds (F (1/45) = 3.94, p < .06), Attention X Warning X Linear Seconds (F (1/45) = 5.16, p < .05), and Warning X Linear Seconds (F (1/45) = 25.53, p < .001) interactions. In the context of the deceleration during the inter-stimulus interval on warned trials, and the subsequent acceleration on all trials, these effects do not appear to be highly meaningful.

Task Motivation

Because the questionnaire response data were limited, an overall analysis was not conducted. Results from the two groups surveyed, however, were similar. The tasks

were considered moderately difficult, of midline interestingness, and slightly unpleasant. Individual analyses of the interestingness data for each group revealed only a Sequence Order X Stimulus interaction (F (1/7) = 8.37, $p < .025$) for group three. No other main effects of interactions achieved significance.

Blink Response

Probability. The analysis of response probability reveals main effects of warning (F (1/45) = 7.85, $p < .01$) and stimulus modality (F (1/45) = 9.15, $p < .01$). The probability of a blink reflex was greater when subjects were warned prior to the presentation of the eliciting stimulus. The probability of a blink reflex was also greater when the eliciting stimulus was an airpuff whether or not the warning stimulus was presented. The effect on response probability of manipulating stimulus presentation frequency is complicated, however, by a significant Attention X Group interaction (F (2/45) = 3.34, $p < .05$). The overall probability of a response in each attention condition is greater for the attend-puff condition in Group One, the two to one ratio, but is greater for the attend-noise condition in the other groups. This shift reflects the greater effect of warning on responding during the attend-puff conditions in those experiments (see Appendix B for group by group results).

Latency. In the overall analysis of response latency, a main effect of warning (F (1/45) = 75.36, $p <<$

.001) reflects the strong and consistent facilitatory effect of a warning stimulus on blink latency. A tendency for noise-elicited blinks to be longer in latency than puff-elicited blinks was also significant in the overall analysis (F (1/45) = 6.42, p < .025).

Inspection of the data from each group indicates that while the effects of warning and stimulus were consistent from sample to sample, the baselines upon which these effects appear varied dramatically from about 35 ms in group one to 52 ms in group two, with group three intermediate at about 45 ms. This difference from sample to sample is reflected by the significant main effect of group (F (1/45) = 33.11, p << .001). The overall analysis did not find any significant interaction involving the group factor.

Amplitude. The main effect of group failed to achieve significance in the analysis of response amplitude (F < 1) as did the interactions involving group. Thus, the hypothesis that changing the stimulus presentation ratio affects response amplitude was not supported.

Warned stimuli elicited reflex blinks of larger amplitude than did stimuli on trials on which the warning stimulus was omitted (F (1/45) = 26.97, p << .001). This potentiating effect of warning was greater for noise-elicited responses (Warning X Stimulus interaction, F (2/45) = 7.92, p < .01), and was greater for responses

elicited while subjects were judging airpuffs (Attention X Warning interaction, F (2/45) = 6.51, $p < .025$).

A consistent pattern of responding across both Experiments I and II showed responding potentiated in the attend-puff condition, especially the responses on warned trials. In addition to the significant Attention X Warning interaction, the combined analysis also revealed a main effect of attention (F (1/45) = 4.56, $p < .05$). One of the four hypotheses, the attend-puff potentiation hypothesis, predicted this consistent, potentiated responding to both stimulus types while subjects are selectively attending to airpuffs.

In order to further investigate the responses relevant to this hypothesis, post-hoc analyses were conducted for data from warned and unwarned trials separately. No effect or interaction involving group was found (F's < 1). However, a main effect of attention did achieve significance (F (1/45) = 8.38, $p < .01$), but only for warned trials. These data indicate that warned responses elicited by stimuli in both modalities were of larger amplitude when subjects were selectively attending airpuffs than when they were attending noise. Further, these data indicate that the response potentiation was found across stimulus presentation ratios employed in Experiment II.

Response habituation. Because it is possible that habituation plays an important role in the results

obtained in this paradigm, analyses were run which specifically looked for effects of habituation. For each subject, responses during the first trial sequence only were analyzed. This produced a between groups variable of trial sequence contrasting subjects judging noise with those judging airpuff. Warned trials for each stimulus were divided into those presented during the first and second halves of the sequence for purposes of examining response habituation. Unwarned trials were not assessed because only six (3 puff, 3 noise) such trials occurred in a given trial sequence. Details of the habituation data are included in Appendix A.

For each measure, blink probability (F (1/42) = 4.84, $p < .05$), latency (F (1/42) = 6.95, $p < .025$), and amplitude (F (1/42) = 39.96, $p < .001$), the main effect of half was significant. No other main effect or interaction achieved significance in any of the analyses of habituation.

Discussion

The most prominent and consistent result from the current experiment is a facilitatory effect of warning. In all experiments, latencies were shortened and magnitudes potentiated on warned trials as compared with unwarned trials. The comparison of warned versus unwarned trials has been used to assess the effects of attending versus not attending (Bohlin & Graham, 1977; Bohlin et

al., 1981; Silverstein et al., 1981). An interpretation based on this comparison would conclude that on warned trials subjects were in a state of generalized attention to sensory input which included at least the cutaneous and auditory channels.

A difference between the experimental paradigms used in these experiments and most of the previous work is the number of types of stimuli capable of eliciting a reflex blink which each subject received. Previous work used a stimulus within a single modality for any given subject. Typically subjects are given a task which involves attending toward or away from the modality in which a reflex eliciting stimulus is presented. The reflex stimulus is then presented either alone or simultaneously with a non-startle stimulus, and, unwarned during the inter-trial interval. Using acoustic stimuli, this paradigm has produced response facilitation when task-relevant stimuli were tones (modality matching, Bohlin & Graham, 1977) and inhibition when they were electrotactile stimuli delivered to the forearm of the subject (modality mismatching, Silverstein et al., 1981). The exceptions to this approach were two studies in which either of two eliciting stimuli could occur on a given trial (Anthony & Graham, 1983, 1985). These studies manipulated attention by the use of a foreground stimulus. In these cases, subjects were processing continuous information presented in the to-be-attended channel which encouraged selective

attending. In the current experiments, subjects were instructed "to be ready for" a stimulus in a particular sensory channel, but, since irrelevant stimuli occurred only on trials without relevant stimuli, there was little reason for them to limit their attentional focus to a single channel. It would, therefore, be possible, that the warning stimulus produced in subjects a state of generalized attention--akin to orienting--which was directed toward and distributed among, but not necessarily limited to, both the sensory channels in which reflex stimuli could appear.

An alternative explanation might suggest that a state of negatively valent affect existed on warned versus unwarned trials. Emotional valence has been convincingly demonstrated to affect the reflex blink with negative valence potentiating the response (Bradley et al., 1989; cf. also the review by Lang et al., 1989). There is also some intuitive validity to the notion that the requirement to make a difficult judgement is a negatively valent situation.

The ratings of task pleasantness which were collected in groups two and three provide a direct indicator of the presence or absence of negative affect during each trial sequence. These ratings, which indicate an average pleasantness score of 47 (on a scale of 0 to 100), suggest that the valence of the situation was just slightly on the unpleasant side of midline (50). If the midline may be

viewed as neutral affective valence, then the task situation was, on the whole, considered only slightly negative by subjects. Such a marginal vote towards negative valence by the current sample of subjects is unlikely to have produced such a marked potentiation as was seen on warned trials.

While such an effect cannot be ruled out, it would seem more likely that the potentiation of responding on warned trials in the current experiments represents an effect, perhaps similar to generalized orienting, in which subjects are focusing their attention on acoustic and cutaneous sensory channels.

These experiments were undertaken with the purpose of replicating and providing clarification of the results obtained by Haerich (1988) and further examining the possible variables controlling these results. The primary finding of Haerich (1988) was a relative inhibition of noise-elicited blinks when subjects were judging noise stimulus durations as compared to the condition in which they were judging airpuff durations. This result was replicated in both experiments, appearing as a relatively greater warning potentiation in the attend-puff condition.

Four hypotheses were suggested which could account for the results obtained by Haerich (1988). These hypotheses differed in their predictions regarding the effects which would have been observed on cutaneously elicited responses in the absence of ceiling effects.

These hypotheses also differed in their predictions regarding the effect of manipulating the ratio of task-relevant to task-irrelevant stimuli.

The interference inhibition hypothesis (number two in figure 1), predicts that attending to a task-relevant stimulus produces inhibition of the response to that stimulus relative to the condition in which the stimulus is not task-relevant. Therefore, acoustically elicited responses would be inhibited in the attend-noise condition relative to the attend-puff condition, while cutaneously elicited responses would be relatively inhibited in the attend-puff condition. In Experiment II--and to a lesser extent in Experiment I--the airpuff stimulus intensity was decreased so that responding was lowered from ceiling. The result was that responding to cutaneous stimuli was consistently potentiated in the attend-puff condition, opposite to the prediction of the hypothesis. This hypothesis, therefore, does not satisfactorily explain the results observed in these experiments.

The habituation hypothesis (number three in figure 1) predicts that differences in mean responding are due to differential habituation which occurs under different stimulus presentation regimes. This hypothesis predicts that for the groups in which one stimulus was presented twice as often as the other (groups one and three), responses to the more frequent stimulus would be reduced more so than responses to the less frequent one. In group

two, where both stimuli were presented with equal frequency, no differences would be expected. Again, this was manifestly not the case. Responding to both stimuli while judging airpuffs was potentiated relative the attend-noise condition regardless of changes in presentation frequency. In addition, response habituation was explicitly investigated in each frequency condition of Experiment II. Though response amplitude did habituate, this habituation was not different across task conditions, stimuli, or, as is demonstrated in the combined analysis, presentation frequencies. Thus, this hypothesis, too, fails to explain satisfactorily the results observed in these experiments.

A third hypothesis (number four in figure 1) suggested that a generalized response sensitization was induced by the task condition in which airpuffs were presented with greater frequency. This hypothesis predicts that whichever attention condition has the most airpuffs presented will have the largest noise as well as puff responses. This prediction was tested by Experiment II, particularly in the condition in which task relevant stimuli occurred less frequently than irrelevant ones. Since potentiation did not depend on the ratio of puffs to noise, this third hypothesis, as well, does not satisfactorily explain the results.

A final hypothesis which was proposed above (number 1 in figure 1) suggests that when attention is directed

towards the cutaneous modality by instructing subjects to discriminate airpuff durations, a generalized response facilitation results. This hypothesis would predict that in all groups, for both experiments, responding would be facilitated in the attend-puff condition regardless of the eliciting stimulus. This, in fact, occurred.

The experiments provide consistent response amplitude results consonant with this position. Both Experiment I and the overall analysis of Experiment II reveal a significant main effect of attention, and a significant interaction of Attention X Warning which does not interact with presentation ratio. Subsequent analysis also indicated that, for warned trials alone, responding in the attend-puff condition was potentiated with respect to the attend-noise condition.

The data from Experiments I and II show that besides the response facilitation due to warning, a response potentiation occurs which is associated only with the attend-puff condition. It is not manipulated by stimulus presentation frequency. It was suggested by Haerich (1988) that the responding might be potentiated by an increase in orienting produced by the greater task difficulty of the airpuff discriminations. Task difficulty was operationally equated in Experiment II by equalizing performance across both stimulus types. Nevertheless, the attend-puff potentiation persisted. Subject ratings indicate that discriminating both stimulus

types was considered moderately difficult but neither discrimination was judged significantly more difficult than the other.

The current results could be explained if the task of discriminating the airpuffs was more affectively negative than discriminating the noise. However, just as data are lacking to support the position that the attend-puff potentiation reflects difficulty-induced orienting, they are equally lacking in support of this affective explanation. The ratings do not indicate any difference in perceived pleasantness between attention conditions.

Thus, neither an explanation of the attend-puff potentiation in terms of difficulty or negative affect was supported by the data. At present, this effect may, at best, be described as a generalized response potentiation associated with instructions for subjects to discriminate cutaneous stimuli.

The potentiation was observed only in the amplitude of the blink response. Heart rate responding does not reveal any differences among conditions. Such a situation is consonant with an interpretation in terms of attention. A deceleration of heart rate can index the occurrence of attending but typically does not distinguish among attention conditions (Graham, 1979).

Blink latencies are reduced by warning, but no differences between attention conditions were found. A reduction in blink latency typically accompanies amplitude

potentiation and, like cardiac deceleration, can index attending (Bohlin & Graham, 1977; Bohlin et al., 1981). Blink latency also may be reduced when amplitudes are inhibited while subjects attention is directed away from the blink stimulus (Silverstein et al., 1981) and reflect the additional attention given an interesting foreground stimulus (Anthony & Graham, 1985). It is, thus, noteworthy that the blink amplitude potentiation observed in the attend-puff condition of the current experiments is not reflected in the latency data, suggesting a distinction between the currently observed attend-puff potentiation and the selective attention effects reported by previous researchers.

In sum, these experiments have demonstrated a potentiating effect of directing attention to a periorbital airpuff stimulus. The effect is not due to a sensitizing effect of the airpuff stimulus itself as it does not occur when attention is directed to noise stimuli, even when the number of such stimuli in the sequence is increased. It is not due to task difficulty which was equated in the current research both in terms of task performance and subject ratings, nor, is it due to negative affect which was likewise constant across task conditions. Rather it seems to be associated with the processing of cognitively important airpuff/sensory input itself.

CONCLUSION

Two important results from the current experiments should be re-emphasized here. First, reflex blinking to both stimuli was found to be potentiated by a warning stimulus in both attentional conditions. It is suggested that, since either stimulus type could occur on a given trial, subjects did not limit their attentional resources to the modality of the task-relevant stimulus, indeed there was no reason to do so. The response facilitation on warned trials, then, results from subjects' generalized orienting of their attention toward sensory inputs. This result was observed in Experiment I and in each group of Experiment II, a consistency indicating the strength of the general attentional manipulation.

The second important result was that the reflex amplitude for both stimulus types was further potentiated when subjects were judging airpuff stimuli. This effect is not due to a sensitizing influence of the airpuff stimulus or to factors involving task difficulty or negative affect. Rather, it seems to be associated with the cognitive set to process the airpuff/sensory input itself.

This effect, which also occurred in all groups of Experiment II, may have strong implications for future theoretical and empirical investigations of selective attention and the processing of sensory information. That a (greater) potentiation occurred when subjects were judging airpuffs as against noise stimuli suggests that the operation which calls or forwards sensory input for processing is not unitary across modalities. The cognitive set which develops when salience is imputed to auditory stimuli is not equivalent to that for salient cutaneous input.

That there may be something intrinsically different between the periorbital cutaneous and acoustic analyzers may be suggested at a deeper level than differences in receptors, etc. Fundamental differences between the two blink reflexes may be found in the underlying neural circuitry; only in the cutaneous blink reflex is an oligosynaptic component found (Shahani & Young, 1973). Too, the relationship between the intensity of sensory input and motor output differs between the two. A recent study found that a cutaneous stimulus which is rated the same psychophysical intensity as a given acoustic stimulus produces much larger responses (Woods & Haerich, 1989). It also appears that the facilitatory effect of increasing intensity across pairs of acoustic and cutaneous stimuli which have been rated as equally intense proceeds at a different rate in the two modalities (Haerich et al.,

1989). Finally, this stimulus which elicits the acoustic response may be considered a distal stimulus in contrast to the proximal stimulus necessary to elicit the cutaneous response. The difference in stimulus proximity suggests that the cutaneous reflex may be more specifically defensive in nature than the acoustic reflex. Taken together, the above suggests that distinctly different mechanisms might be involved in receiving sensory information for processing from auditory and tacto-periorbital inputs.

Further investigations should be directed towards defining more precisely the factors involved in this attend-puff potentiation. The effect may be produced by the marshalling of attentional resources when periorbital cutaneous stimuli are salient. The relevant comparison, then, is between warned stimuli with and without a task requirement. An experiment in which blink responses are recorded before and after institution of a task (e.g., duration discrimination) requirement might provide important evidence regarding this suggestion. A two-phase paradigm, similar to those used to assess conditioning independent of acquisition curve limitations (Rescorla, 1988) might be designed; in the first phase, blink responses to noise and airpuff stimuli without a task would be recorded; in the second phase, while recording blinks from the same stimuli, groups of subjects would be required to discriminate noise or airpuff durations, or

perform an equivalent task involving neither stimulus modality (task control), or repeat phase one (non-task control). This is also an important manipulation because recent work (Haerich et al., 1989) has shown dramatic effects on the relationship between stimulus intensity and blink reflex amplitude depending on the presence or absence of cognitive task requirements.

If the effect depends upon directing attentional resources toward the task, it might be possible to manipulate the motivational context by providing rewards and punishments for task performance. By providing feedback to the subject on task performance, offering rewards for correct performance and/or punishment for incorrect performance, and varying the intensity of each, motivation to perform the task might be brought under control.

Additional foci for future research would include the question of the differences in the result from the current experiments and those of Hackley and Graham (1983). In that study, warned blinks were inhibited as compared with unwarned; also, attending toward and away from reflex eliciting stimuli produced facilitating and inhibiting effects respectively. Three specific methodological differences between the Hackley and Graham study and the present ones include: 1) the current study elicited blinks from two stimulus modalities for each subject within each trial sequence while the Hackley and Graham

experiments used only one modality of eliciting stimulus per subject, 2) stimuli were presented individually in the current experiments while in Hackley and Graham each trial included a compound stimulus consisting of a blink eliciting stimulus plus a non-eliciting stimulus, and 3) the startling acoustic stimulus was paired with a non-startling puff to the third digit of the left hand rather than with a periorbital airpuff. The effects of each of these variables (number of stimuli, stimulus compounding, location of airpuff presentation) needs to be assessed regarding its effect on blink reflex modulation.

While the blink reflex has proven to be a powerful research tool, important questions remain.

APPENDIX A
DATA: MEANS AND STANDARD DEVIATIONS

DATA: MEANS AND STANDARD DEVIATIONS

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Task Performance (% Correct)				
Experiment I				
Noise First	92.7	6.25	68.4	9.32
Puff First	92.1	16.63	63.2	16.67
Experiment II				
Group One				
Noise First	59.9	13.76	69.7	13.10
Puff First	62.5	10.68	57.2	9.92
Group Two				
Noise First	72.5	9.72	60.8	19.00
Puff First	67.5	14.91	66.7	13.31
Group Three				
Noise First	67.7	17.06	47.5	14.18
Puff First	66.2	20.12	48.1	14.55
Task Motivation (1.0 is max)				
Group Two				
Difficulty				
Noise First	.773	.227	.712	.152
Puff First	.701	.252	.705	.204
Interestingness				
Noise First	.542	.297	.508	.287
Puff First	.587	.165	.480	.197
Pleasantness				
Noise First	.443	.061	.469	.080
Puff First	.497	.158	.492	.145
Group Three				
Difficulty				
Noise First	.630	.383	.715	.340
Puff First	.693	.135	.636	.251

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Interestingness				
Noise First	.552	.165	.515	.160
Puff First	.465	.338	.582	.260
Pleasantness				
Noise First	.472	.118	.383	.173
Puff First	.516	.287	.443	.356
Blink Probability (probability)				
Experiment I				
Warned				
Noise	.973	.051	.976	.064
Puff	.982	.060	.973	.061
Unwarned				
Noise	.921	.233	.968	.100
Puff	.984	.073	1.000	.000
Experiment II				
Group One				
Warned				
Noise	.897	.143	.969	.056
Puff	.992	.031	1.000	.000
Unwarned				
Noise	.875	.206	.958	.114
Puff	.979	.083	.979	.083
Group Two				
Warned				
Noise	.930	.156	.944	.070
Puff	.962	.084	.984	.035
Unwarned				
Noise	.938	.134	.865	.253
Puff	.958	.114	.896	.235

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Group Three				
Warned				
Noise	.961	.088	.917	.138
Puff	.972	.094	.977	.068
Unwarned				
Noise	.875	.206	.833	.243
Puff	.979	.083	.937	.181
Blink Latency (ms)				
Experiment I				
Warned				
Noise	47.0	8.64	46.8	8.60
Puff	45.4	8.25	45.4	7.57
Unwarned				
Noise	53.6	13.33	54.4	9.64
Puff	51.5	7.95	53.3	8.11
Experiment II				
Group One				
Warned				
Noise	37.3	6.41	36.8	4.66
Puff	36.6	7.06	35.0	5.92
Unwarned				
Noise	47.9	7.70	49.0	6.61
Puff	43.5	8.37	41.3	15.28

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Group Two				
Warned				
Noise	53.3	7.41	52.0	7.31
Puff	54.6	7.38	50.0	5.15
Unwarned				
Noise	69.9	9.16	65.4	13.70
Puff	56.8	7.49	61.3	13.82
Group Three				
Warned				
Noise	43.8	6.26	45.1	8.60
Puff	43.5	8.05	44.2	9.89
Unwarned				
Noise	51.6	8.51	52.3	14.42
Puff	49.7	6.97	49.8	9.55
Blink Magnitude (% of mean; a-d units)				
Experiment I				
Normalized Scores				
Warned				
Noise	106.5	25.0	124.2	27.1
Puff	104.1	19.9	108.3	20.4
Unwarned				
Noise	90.8	34.1	78.5	38.5
Puff	96.1	20.2	91.4	27.4
Raw Scores				
Warned				
Noise	813.3	548.7	940.6	580.3
Puff	1220.2	703.1	1223.6	703.6

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Unwarned				
Noise	708.7	614.7	713.6	636.0
Puff	1134.3	700.6	1096.2	744.6
Experiment II				
Group One				
Normalized Scores				
Warned				
Noise	104.3	27.5	125.4	45.6
Puff	94.3	8.5	108.3	27.6
Unwarned				
Noise	85.8	30.8	84.5	33.1
Puff	93.6	30.0	103.2	17.0
Raw Scores				
Warned				
Noise	721.7	472.8	764.4	383.2
Puff	1117.4	396.7	1237.7	398.4
Unwarned				
Noise	612.8	456.4	564.7	415.8
Puff	1106.1	481.2	1216.4	440.7
Group Two				
Normalized Scores				
Warned				
Noise	111.2	40.3	134.2	50.5
Puff	94.3	38.0	125.3	49.3
Unwarned				
Noise	69.8	36.6	84.7	51.2
Puff	76.7	49.0	103.7	48.5

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Raw Scores				
Warned				
Noise	837.3	709.1	996.6	720.5
Puff	1533.7	1020.7	1841.7	960.9
Unwarned				
Noise	663.4	869.6	686.3	788.1
Puff	1305.3	1108.8	1525.2	855.5
Group Three				
Normalized Scores				
Warned				
Noise	103.3	25.1	130.0	32.9
Puff	99.0	24.6	119.8	40.7
Unwarned				
Noise	94.6	34.8	72.2	32.7
Puff	87.2	27.6	94.0	38.7
Raw Scores				
Warned				
Noise	822.8	727.4	907.3	726.9
Puff	1225.0	908.1	1341.0	956.9
Unwarned				
Noise	733.8	677.7	668.4	572.0
Puff	1136.0	871.8	1245.4	1043.8
Habituation of Probability (% of mean)				
Group One				
Noise First				
First Half	102.1	6.9	96.9	8.8
Second Half	96.3	7.7	1.0	0.0

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Puff First				
First Half	101.8	9.2	96.9	5.8
Second Half	98.2	9.2	1.0	0.0
Group Two				
Noise First				
First Half	101.8	5.2	102.8	7.8
Second Half	99.0	2.9	97.7	6.5
Puff First				
First Half	101.3	5.8	101.1	3.2
Second Half	97.0	8.1	99.6	3.2
Group Three				
Noise First				
First Half	101.6	4.8	104.4	13.3
Second Half	98.4	4.8	95.6	13.3
Puff First				
First Half	102.0	5.4	100.0	0.0
Second Half	98.0	5.4	100.0	0.0
Habituation of Latency (% of mean)				
Group One				
Noise First				
First Half	98.3	5.1	97.1	4.4
Second Half	102.0	5.2	102.5	3.4
Puff First				
First Half	100.1	3.8	99.6	2.5
Second Half	99.9	3.8	100.3	2.3
Group Two				
Noise First				
First Half	96.2	4.7	98.2	1.8
Second Half	103.9	4.5	101.7	1.7

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Puff First				
First Half	97.5	3.9	97.5	1.7
Second Half	102.5	5.1	108.0	1.8
Group Three				
Noise First				
First Half	99.3	5.2	99.1	2.0
Second Half	100.7	1.2	98.3	7.6
Puff First				
First Half	104.0	4.2	98.3	2.1
Second Half	96.0	9.7	101.6	2.1
Habituation of Magnitude (% of mean)				
Group One				
Noise First				
First Half	114.6	17.2	106.9	9.4
Second Half	85.1	18.6	93.4	9.2
Puff First				
First Half	118.8	17.8	109.1	11.2
Second Half	81.2	15.2	91.4	10.6
Group Two				
Noise First				
First Half	128.2	20.1	136.9	65.5
Second Half	75.1	22.1	82.0	19.0
Puff First				
First Half	129.3	30.9	114.3	18.4
Second Half	80.1	27.0	82.9	23.1

Table--Continued

	JUDGE NOISE MEAN	JUDGE NOISE STD DEV	JUDGE PUFF MEAN	JUDGE PUFF STD DEV
Group Three				
Noise First				
First Half	115.3	15.2	105.5	6.8
Second Half	84.3	15.2	91.8	12.2
Puff First				
First Half	105.4	24.2	112.4	13.0
Second Half	94.7	23.9	87.6	16.8

APPENDIX B: EXPERIMENT II: GROUP BY GROUP RESULTS

The primary purpose of Experiment II was to assess the effect of varying the frequency with which task relevant stimuli were presented. The results of this manipulation and their implications for the various hypotheses proposed to explain the results of the Haerich (1988) study were presented above.

In that analysis, significant effects of manipulating the ratio of task-relevant and irrelevant stimuli were observed. These effects did not materially affect the major results. It is, however, appropriate to consider a group by group analysis of the experiment at this time. These groups differed mainly in the ratio of task-relevant to task-irrelevant stimuli. These ratios were two to one, one to one, and one to two for groups one, two, and three respectively.

Task Motivation

Results for the motivation rating-questionnaire were similar for both groups two and three (data were not available from group one, see above). The discrimination task was considered moderately difficult, of midline interest, and slightly unpleasant (figure 7). Analyses of these data do not reveal any significant main effects or

interactions in subjects' rating of task difficulty, nor on task pleasantness. Regarding interestingness, for group three, the Order X Stimulus interaction was significant (F (1/7) = 8.37, $p < .025$), indicating that for both sequences, judging the second stimulus was less interesting than the first.

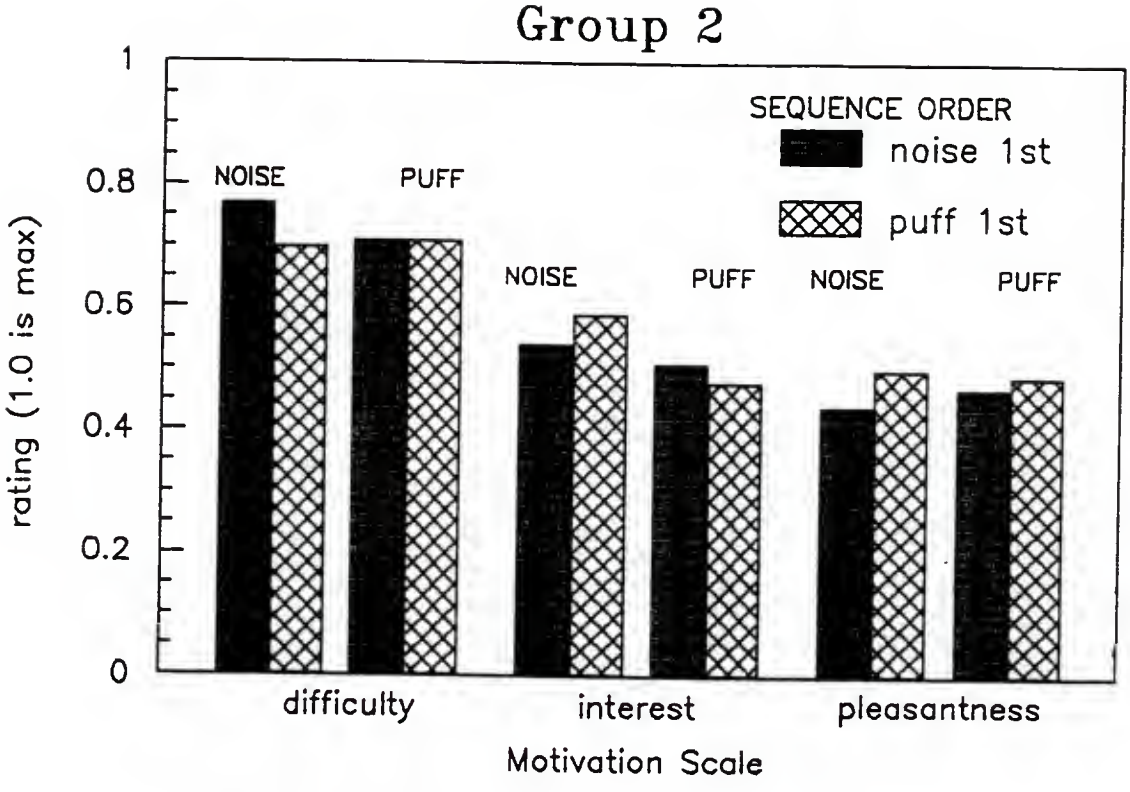
Task Performance

The group one mean percent correct scores of 61 and 63.5 for noise and airpuff judgments respectively indicate that the manipulation of durations did produce roughly equivalent task difficulty (F (1/14) = 1.74, $p > .10$). An inspection of the mean values for sequence order suggests that subjects improved with practice (figure 8). The effect is not significant for judgments of noise ($F < 1$), but does reach significance for judgments of airpuff stimuli (F (1/14) = 4.63, $p < .05$). The practice effect does not occur for groups two and three suggesting that a favorable ratio, such as two to one, is necessary for subjects' airpuff discriminations to benefit from noise practice

When equal numbers of stimuli are presented, as in group two, discrimination of airpuff stimuli was again equivalent to that of noise stimuli ($F < 1$). For neither stimulus type did an effect of stimulus order occur (F's < 1).

As was suggested above, decreasing the frequency of task-relevant stimuli appears to have a greater effect on

Figure 7. Task Motivation: Experiment II. Motivation ratings on each scale, difficulty, interest, and pleasantness. Data from group three represent a sample from nine subjects only.


Group 2
1
0.8
0.6
0.4
0.2
0
rating (1.0 is max)
SEQUENCE ORDER
noise 1st
puff 1st
NOISE
PUFF
NOISE
PUFF
NOISE
PUFF
difficulty
interest
pleasantness
Motivation Scale

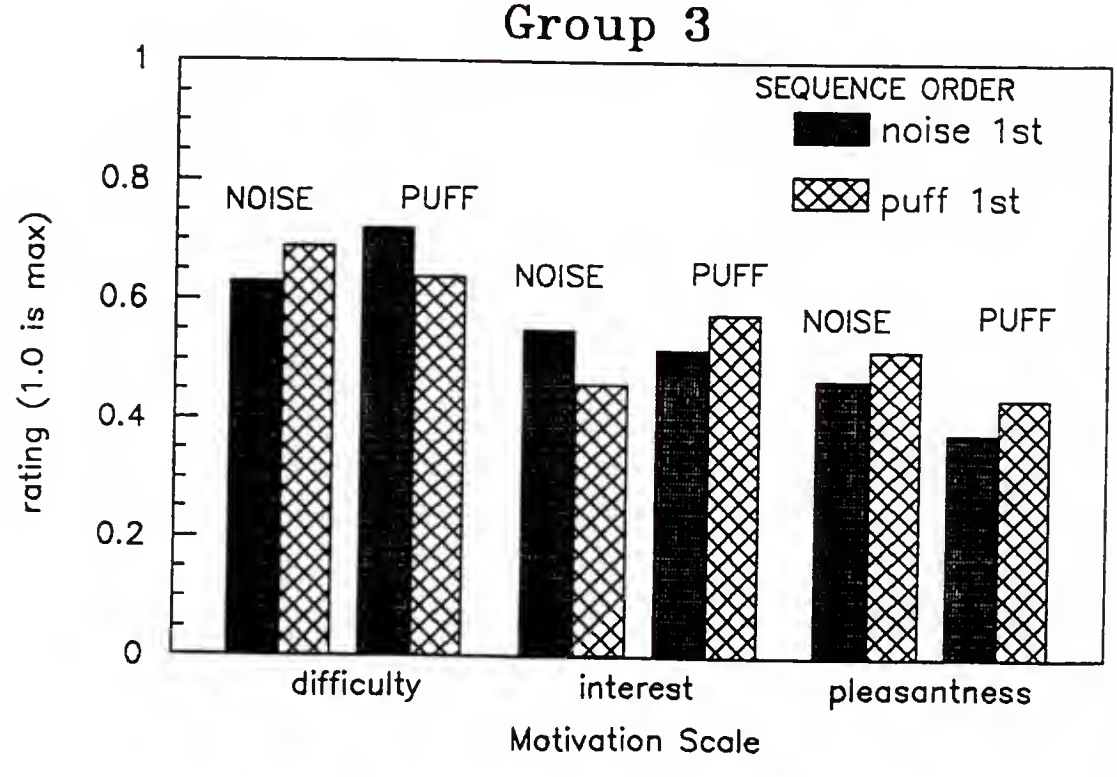
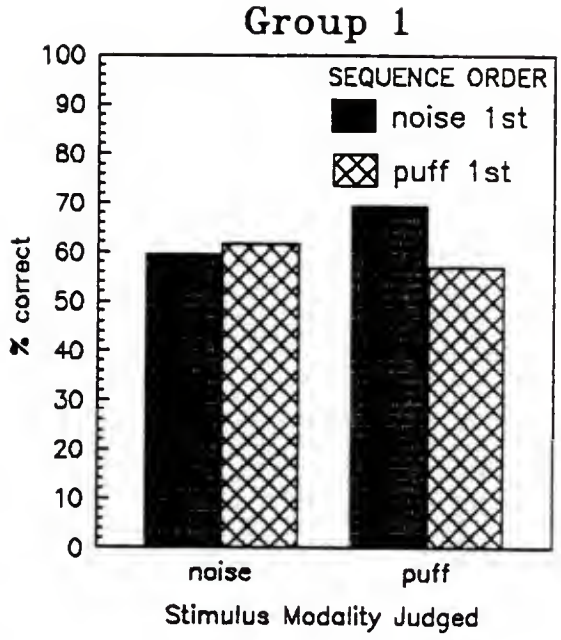
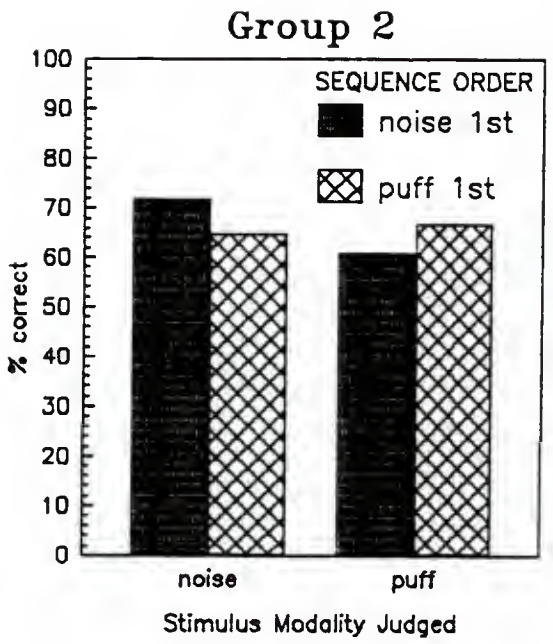

Group 3
1
0.8
0.6
0.4
0.2
0
rating (1.0 is max)
SEQUENCE ORDER
noise 1st
puff 1st
NOISE
PUFF
NOISE
PUFF
NOISE
PUFF
difficulty
interest
pleasantness
Motivation Scale

Figure 8. Task Performance: Experiment II. Group by group percentages of correct discrimination of each stimulus type presented for each sequence order.


Group 1
SEQUENCE ORDER
noise 1st
puff 1st
% correct
100
90
80
70
60
50
40
30
20
10
0
noise
puff
Stimulus Modality Judged


Group 2
SEQUENCE ORDER
noise 1st
puff 1st
% correct
100
90
80
70
60
50
40
30
20
10
0
noise
puff
Stimulus Modality Judged

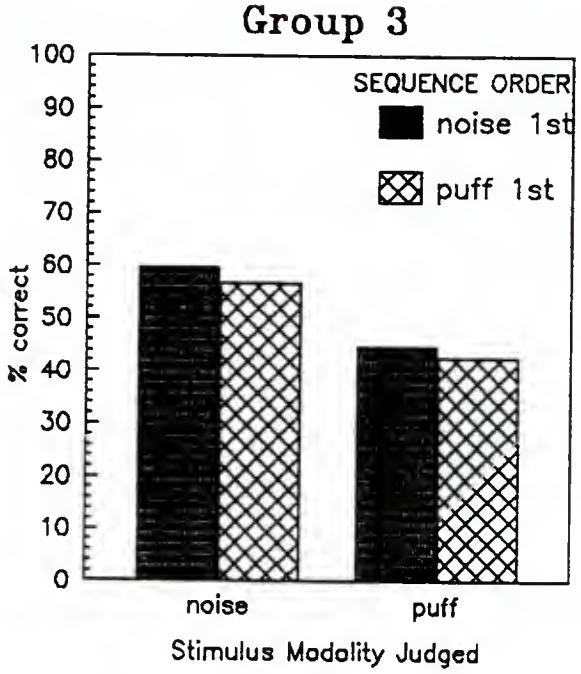
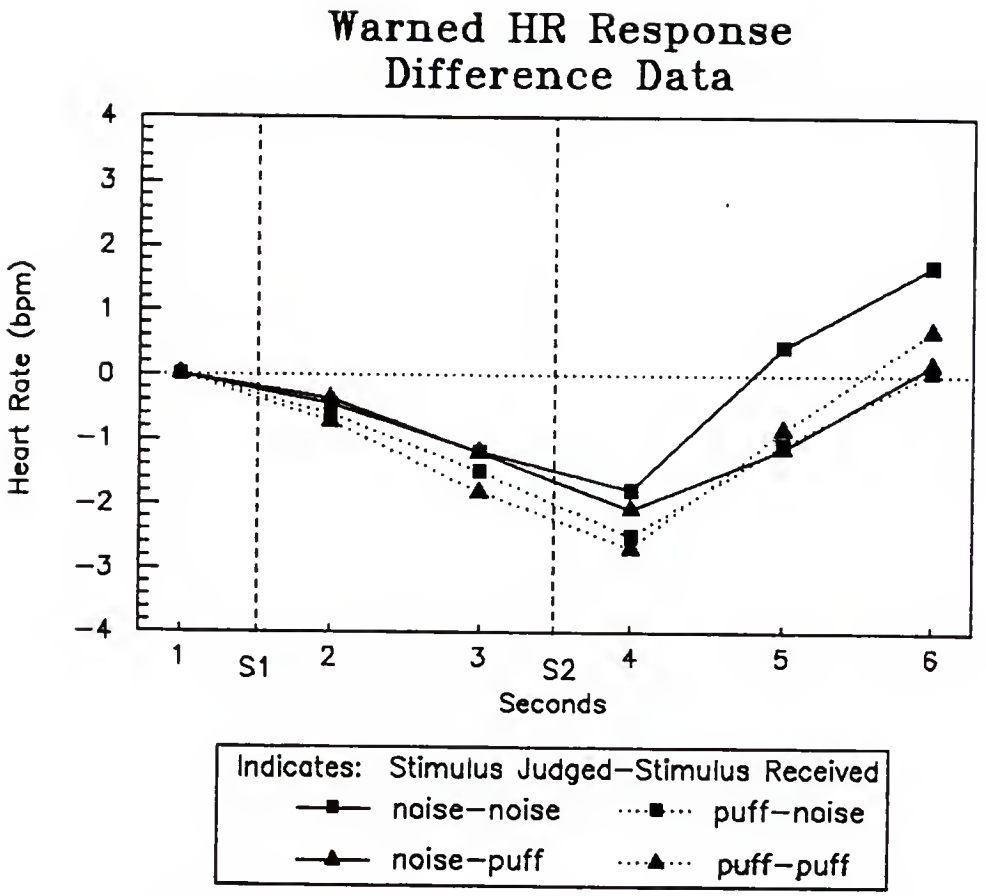

Group 3
SEQUENCE ORDER
noise 1st
puff 1st
% correct
100
90
80
70
60
50
40
30
20
10
0
noise
puff
Stimulus Modality Judged

Figure 9. Heart Rate: Experiment II, Grp 1. Heart rate difference scores on warned and unwarned trials for each condition from group one.


Warned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
S1
2
3
S2
4
5
6
Seconds
Indicates: Stimulus Judged−Stimulus Received
noise−noise
puff−noise
noise−puff
puff−puff

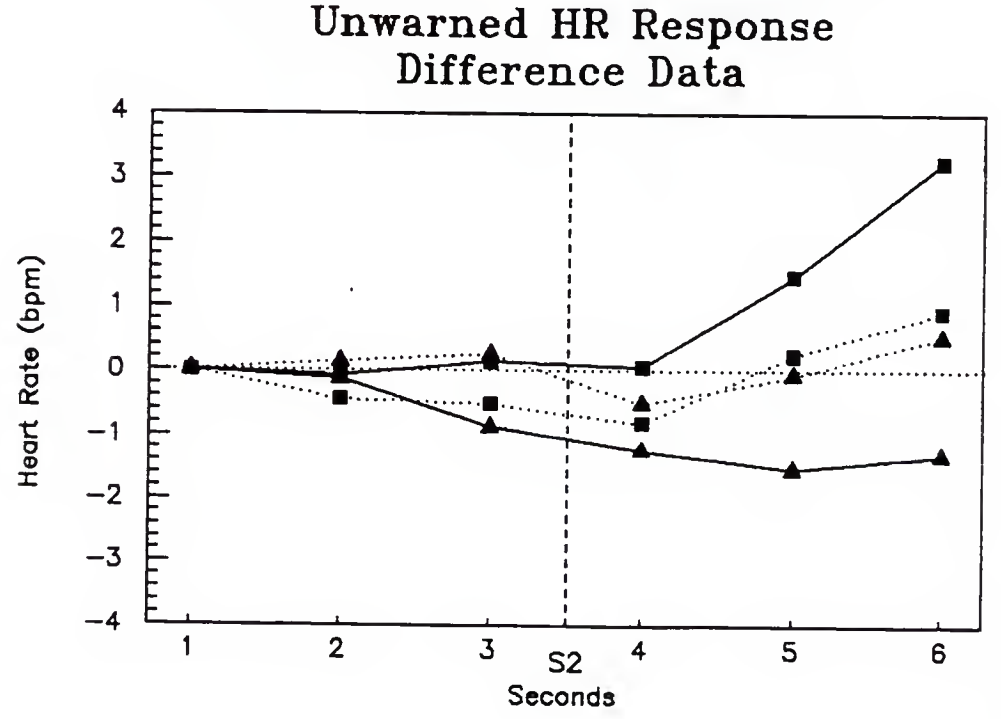
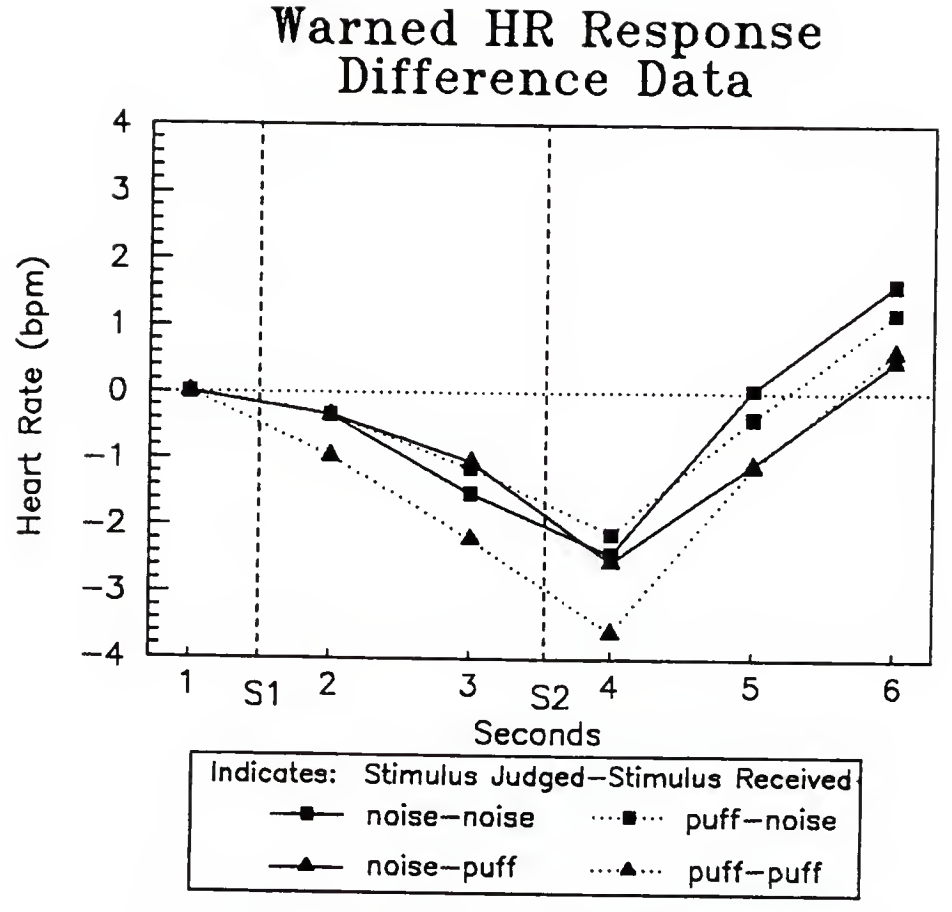

Unwarned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
2
3
S2
4
5
6
Seconds

Figure 10. Heart Rate: Experiment II, Grp 2. Heart rate difference scores on warned and unwarned trials for each condition from group two.


Warned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
S1
2
3
S2
4
5
6
Seconds
Indicates: Stimulus Judged−Stimulus Received
noise−noise
puff−noise
noise−puff
puff−puff

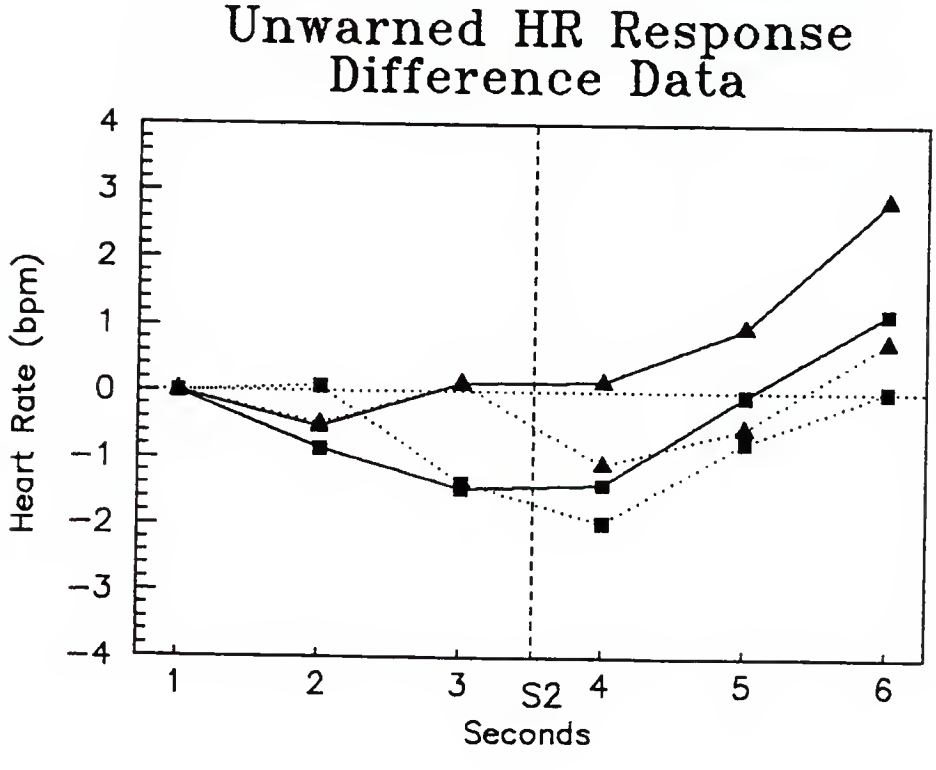
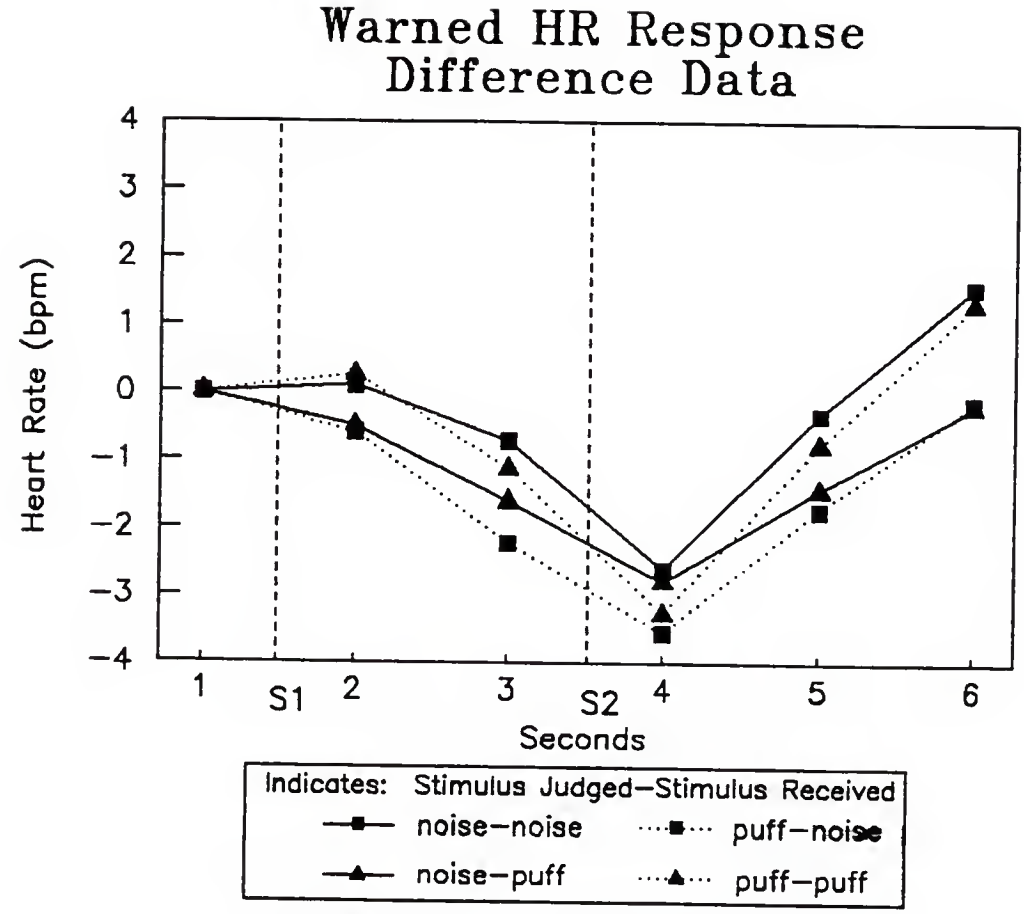
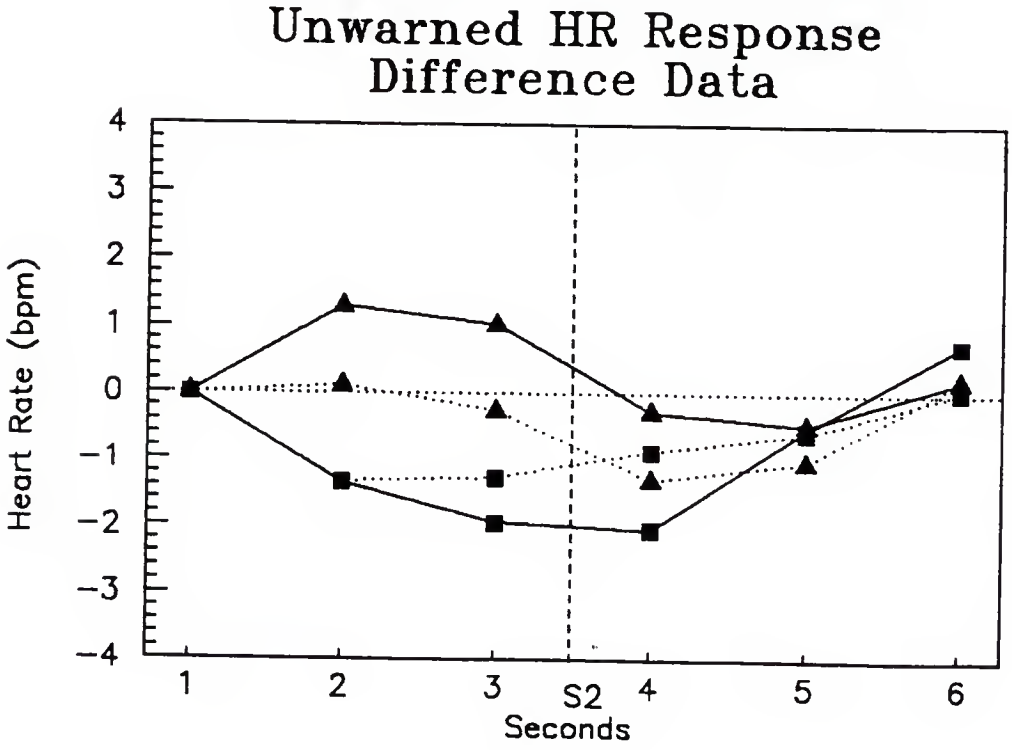

Unwarned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
2
3
S2
4
5
6
Seconds

Figure 11. Heart Rate: Experiment II, Grp 3. Heart rate difference scores on warned and unwarned trials for each condition from group three.


Warned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
S1
2
3
S2
4
5
6
Seconds
Indicates: Stimulus Judged−Stimulus Received
noise−noise
puff−noise
noise−puff
puff−puff


Unwarned HR Response
Difference Data
Heart Rate (bpm)
4
3
2
1
0
−1
−2
−3
−4
1
2
3
S2
4
5
6
Seconds

airpuff discriminations than noise. Performance on airpuff discrimination was significantly worse than that on noise stimuli (F (1/14) = 14.02, $p < .01$). The effect of sequence order did not achieve significance (F's < 1).

Heart Rate

The heart rate data are presented separately for each group in figures 9, 10 and 11. As may be readily observed, the pattern found in the overall analyses is common to each group. On warned trials only, prior to the reflex stimulus a deceleration occurs in all conditions. An acceleration occurs after the reflex stimulus in all conditions whether or not a warning stimulus was present.

The deceleration is reflected in analyses of seconds one through four.

For group one, an ANOVA shows main effects of warning (F (1/15) = 8.27, $p < .025$), of linear seconds (F (1/15) = 32.52, $p < .001$), and a Warning X Linear Second interaction (F (1/15) = 7.34, $p < .025$).

For group two, the linear trend across seconds was significant (F (1/15) = 8.35, $p < .025$) and a subsequent analysis of unwarned trials only failed to find any linear trend across seconds ($F < 1$) indicating that the acceleration occurs only on warned trials.

For group three, main effects of linear seconds (F (1/15) = 24.21, $p < .001$) and quadratic seconds (F (1/15) = 9.98, $p < .01$), as well as Warning X Linear Seconds (F

(1/15) = 6.49, $p < .025$) and Warning X Quadratic Seconds (F (1/15) = 5.21, $p < .05$) interactions reached significance.

Analyses of the accelerations subsequent to the reflex stimulus, across seconds 4 through 6 are complicated as their slopes and points of origin differ.

For group one, the analyses reveal a main effect of linear seconds (F (1/15) = 35.28, $p < .001$), as well as Warning X Linear Seconds (F (1/15) = 6.29, $p < .025$), and Stimulus X Warning X Linear Seconds (F (1/15) = 6.44, $p < .025$) interactions, with the greater variance found among the attend-noise than attend-puff trials producing Attention X Stimulus (F (1/15) = 5.29, $p < .05$) and Stimulus X Linear Seconds (F (1/15) = 8.07, $p < .025$) interactions.

For group two, a significant linear trend across seconds (F (1/15) = 24.62, $p < .001$) and a Warning X Linear Seconds interaction (F (1/15) = 5.97, $p < .05$) appear.

For group three, a main effect of linear seconds (F (1/15) = 43.95, $p < .001$) and Warning X Linear Seconds (F (1/15) = 14.05, $p < .01$) and Attention X Stimulus X Linear Seconds interactions (F (1/15) = 9.65, $p < .01$) reach significance.

While a number of interactions did reach significance in the analyses of seconds 4 through 6, there is no discernable pattern nor consistency across groups. These effect do not overshadow or qualify the primary response pattern of deceleration after a warning stimulus and

acceleration after the reflex stimulus which was found in the overall analysis.

Blink Probability

Remaining above 0.8, blink probability was high throughout the experiment. However, the probability of a response to a cutaneous stimulus appears more stable than that to an acoustic one. This produces a number of interactions in the individual analyses.

For group one, analysis of variance revealed a significant main effect of attention (F (1/15) = 4.84, p < .05). Inspection of figure 12 suggests that this effect was due to the relatively lower response probability to acoustic stimuli, especially in the attend-noise condition. Indeed the Attention X Stimulus interaction (F (1/15) = 3.74, p = .07) was significant at a marginal confidence level.

For group two, analysis of blink probability revealed no significant main effects or interactions. Inspection of the probability results suggests that omission of the warning stimulus produced a smaller response probability for both eliciting stimuli, but only in the attend-puff condition. This suggestion is support by the Attention X Warning interaction (F (1/15) = 3.87, p = .07) which was significant at a marginal confidence level.

For group three, main effects of warning (F (1/15) = 6.12, p < .05), and stimulus (F (1/15) = 7.56, p < .025) indicate that the probability of a blink response was

greater on warned than on unwarned trials and that this effect was stronger for acoustically elicited responses. This explanation is supported by a significant Warning X Stimulus interaction (F (1/15) = 4.82, $p < .05$). No effects of attention condition were found.

Blink Latency

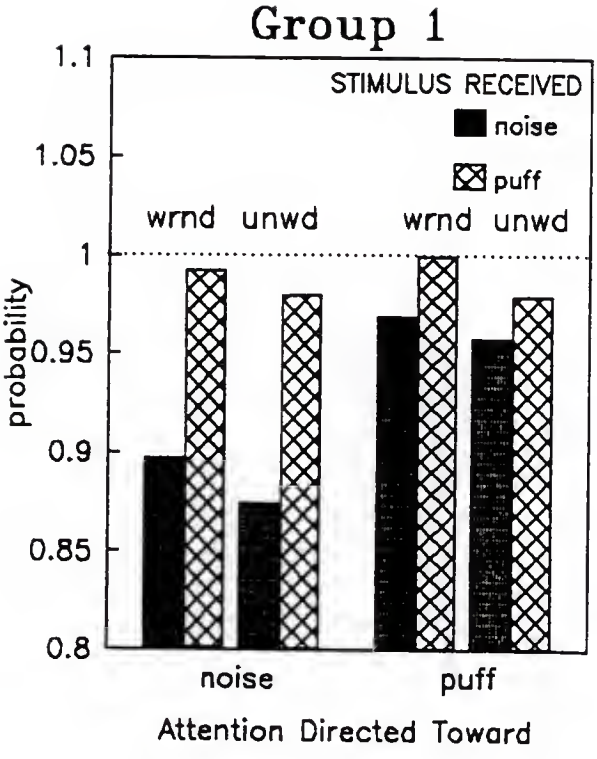
Data for latency are presented in figure 13. As can be seen easily, the there occurs a consistent pattern in which warned responses are at shorter latency than unwarned one with a tendency for noise-elicited responding to be slightly greater in latency than puff-elicited responding. This pattern remains despite shifts totalling nearly 15 ms in the baseline upon which it appears.

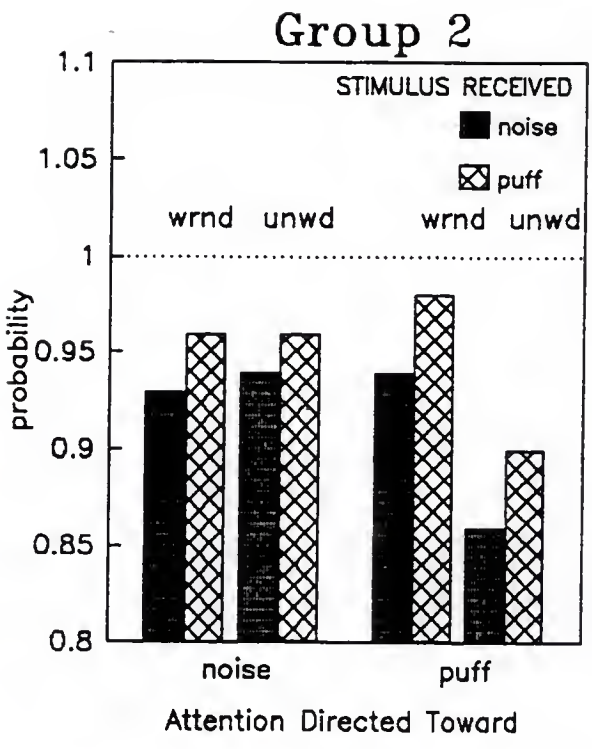
For group one, in addition to the main effect of warning (F (1/15) = 22.40, $p < .001$), the ANOVA also revealed a main effect of stimulus (F (1/15) = 5.45, $p < .05$).

For group two, the effect warning was significant (F (1/15) = 34.41, $p < .001$). This warning facilitation was greater for noise-elicited responses than for puff-elicited responses (Warning X Stimulus interaction, F (1/15) = 6.06, $p < .05$).

For group three, reflex latencies on warned trials were shorter than on unwarned (F (1/15) = 20.68, $p < .001$). No other main effects of interactions reached significance.

Figure 12. Blink Probability: Experiment II. Group by group probabilities of a reflex blink on warned and unwarned trials for each attention condition.


Group 1
STIMULUS RECEIVED
noise
puff
wrnd unwd wrnd unwd
probability
1.1
1.05
1
0.95
0.9
0.85
0.8
noise
puff
Attention Directed Toward


Group 2
STIMULUS RECEIVED
noise
puff
wrnd unwd wrnd unwd
probability
1.1
1.05
1
0.95
0.9
0.85
0.8
noise
puff
Attention Directed Toward

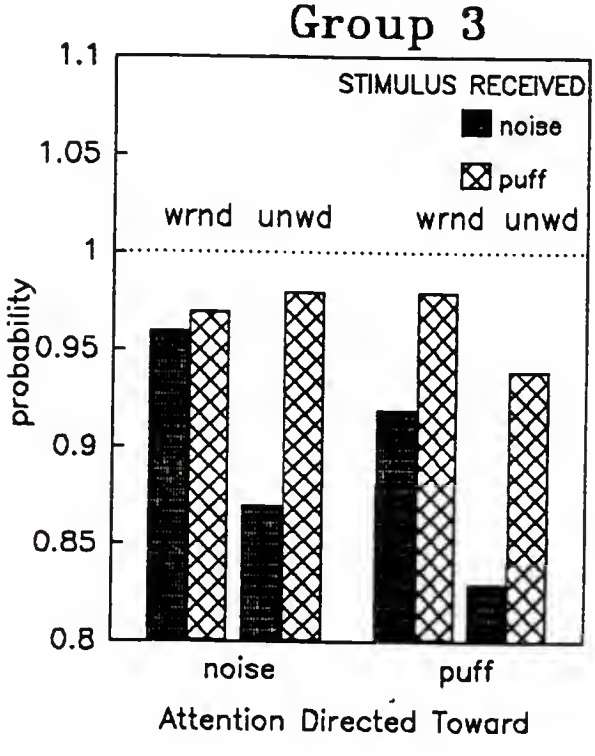
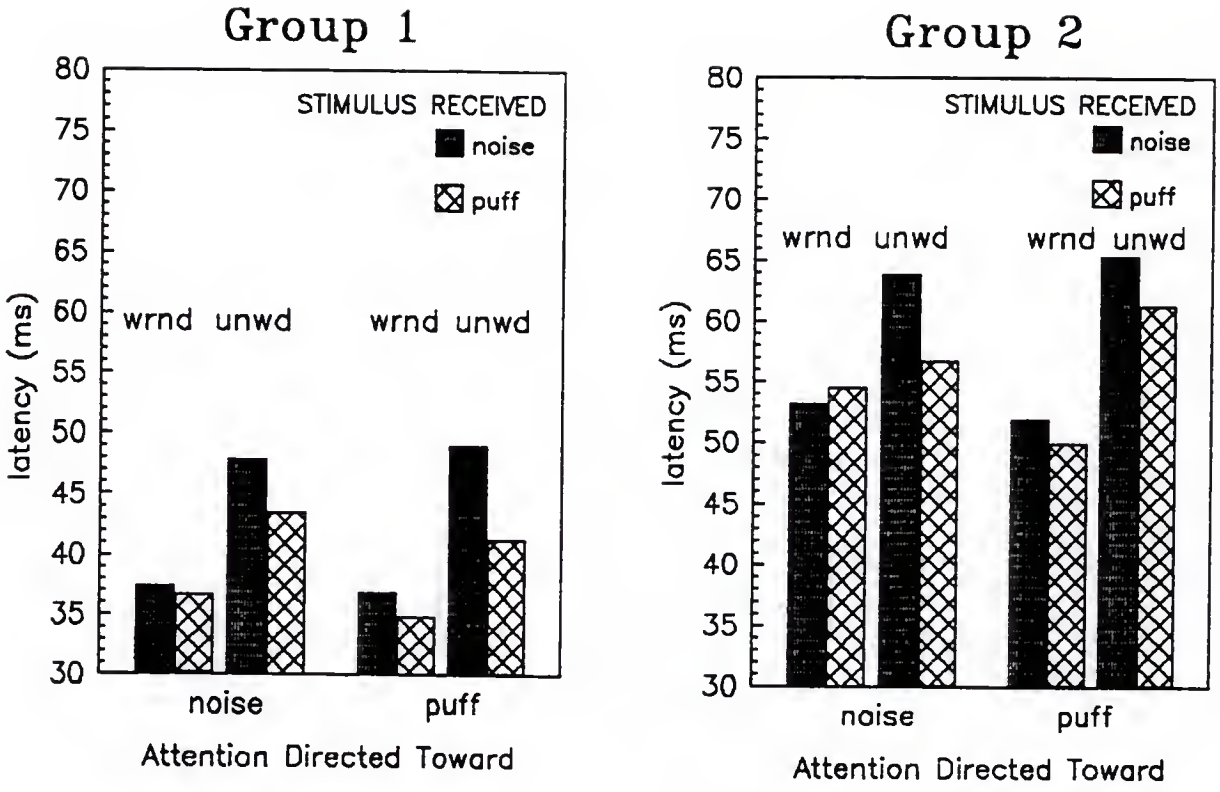

Group 3
STIMULUS RECEIVED
noise
puff
wrnd unwd wrnd unwd
probability
1.1
1.05
1
0.95
0.9
0.85
0.8
noise
puff
Attention Directed Toward

Figure 13. Blink Latency: Experiment II. Group by group latencies of reflex blinking on warned and unwarned trials for each attention condition.


Group 1
STIMULUS RECEIVED
noise
puff
wrnd unwd
wrnd unwd
latency (ms)
80
75
70
65
60
55
50
45
40
35
30
noise
puff
Attention Directed Toward
Group 2
STIMULUS RECEIVED
noise
puff
wrnd unwd
wrnd unwd
latency (ms)
noise
puff
Attention Directed Toward

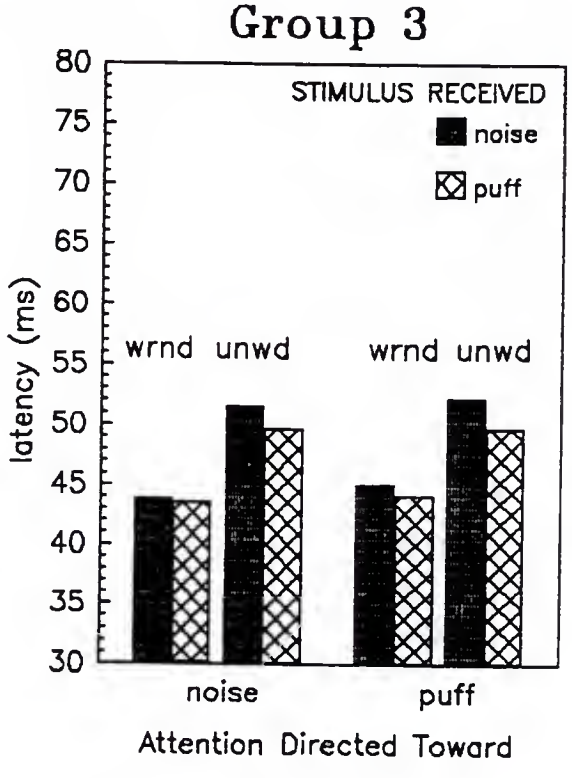
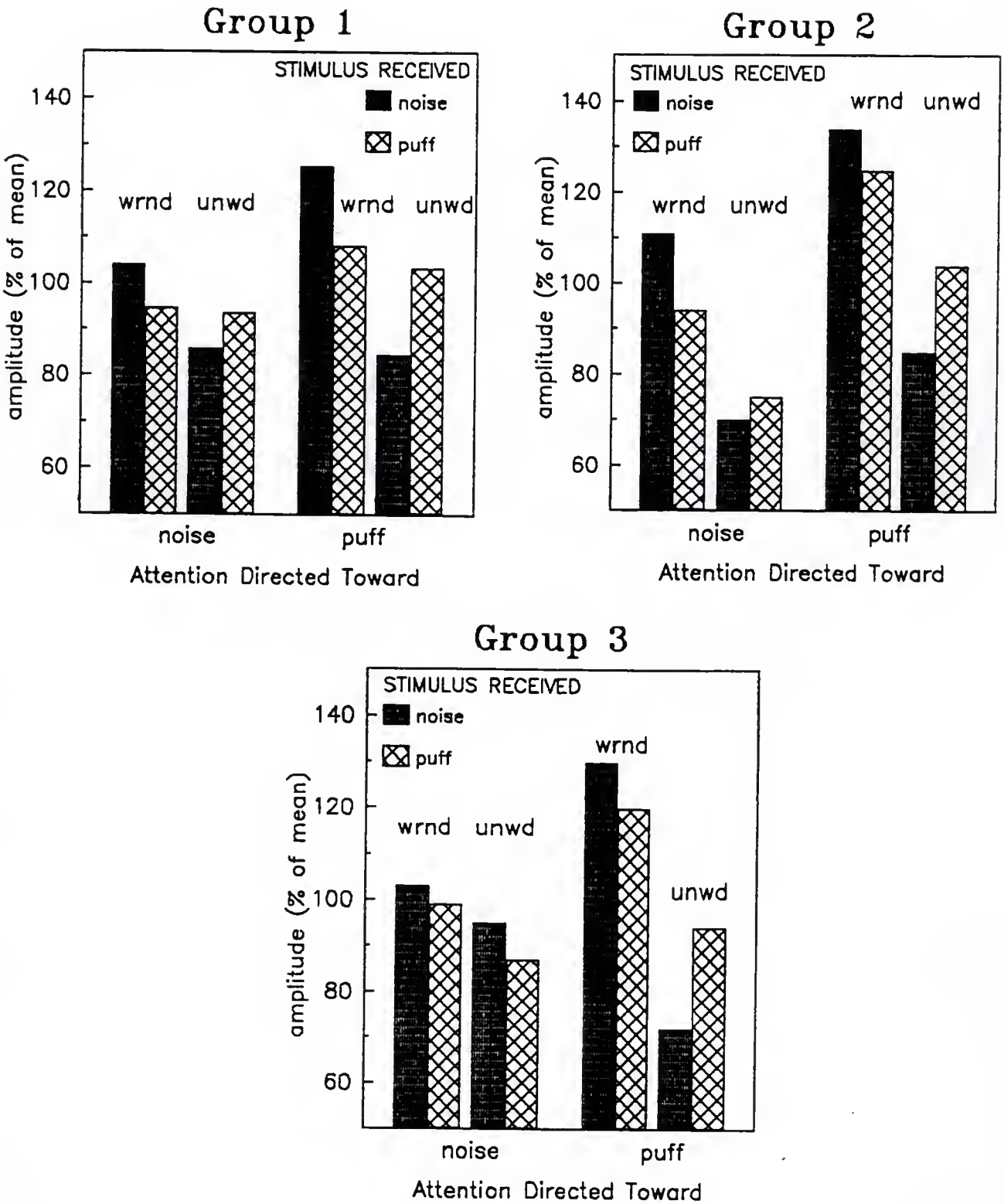

Group 3
STIMULUS RECEIVED
noise
puff
wrnd unwd
wrnd unwd
latency (ms)
80
75
70
65
60
55
50
45
40
35
30
noise
puff
Attention Directed Toward

Figure 14. Blink Amplitude: Experiment II. Group by group amplitudes of reflex blinking on warned and unwarned trials for each attention condition


Group 1
STIMULUS RECEIVED
noise
puff
140
120
100
80
60
amplitude (% of mean)
wrnd
unwd
wrnd
unwd
noise
puff
Attention Directed Toward
Group 2
STIMULUS RECEIVED
noise
puff
140
120
100
80
60
amplitude (% of mean)
wrnd
unwd
wrnd
unwd
noise
puff
Attention Directed Toward
Group 3
STIMULUS RECEIVED
noise
puff
140
120
100
80
60
amplitude (% of mean)
wrnd
unwd
wrnd
unwd
noise
puff
Attention Directed Toward

Blink Amplitude

The results of the overall analysis indicated that responding was facilitate on warned trials as compared to unwarned trials, and that, when subjects were judging airpuffs, greater facilitation occurred than when they were judging noise. As can be seen in figure 14, this effect is consistently reflected in the individual group data.

For group one, besides the facilitatory effect of warning (F (1/15) = 5.49, $p < .05$), a significant Warning X Stimulus interaction (F (1/15) = 5.35, $p < .05$) suggests that that effect of warning appears to be greater for noise-elicited blinks than for puff-elicited blinks. Statistical tests do not reveal significant effects of attention condition in group one.

For group two, analysis of response amplitude revealed only a main effect of warning (F (1/15) = 10.29, $p < .01$).

For group three, not only were reflexes were potentiated by a warning stimulus (F (1/15) = 12.02, $p < .01$), but the interactions of Warning X Attention (F (1/15) = 5.20, $p < .05$) and Attention X Warning X Stimulus (F (1/15) = 4.72, $p < .05$) suggest that this potentiation was especially effective in the attend-puff condition, and, within this condition, for acoustically elicited blinks.

Response Habituation

The overall analysis revealed the each of the blink response measures, probability, latency, and amplitude, habituated across trials during the first trial sequence.

Analyses of individual groups fail to detect such habituation except in the blink amplitude measure. It should also be noted that in no case did an analysis detect a significant effect or interaction involving attention condition.

For group one, analysis of blink amplitude revealed not only a significant main effect of sequence half (F (1/14) = 18.85, $p < .001$) indicating that habituation of blink amplitude did occur, but, the Half X Stimulus interaction also achieved significance (F (1/14) = 4.68, p < .05). Inspection of the means (see Appendix A) suggests greater habituation occurred in acoustically elicited blinks than in those elicited by airpuff.

For group two, response amplitude was found to habituate from the first to the second half of the first sequence of trials independent of stimulus modality (F (1/15) = 15.20, $p < .01$). No other main effects or interactions reached significance in the analyses of habituation.

For group three, amplitude was found to habituate across trials (F (1/15) = 12.60, p , .01), but no significant effects of, or interactions with stimulus modality or attention condition occurred.

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BIOGRAPHICAL SKETCH

Paul Haerich, Tennesseean by birth, Californian by upbringing, received his high school diploma from Forest Lake Academy near Orlando, Florida, in 1979. When he began his undergraduate career he was a cello performance major. He quickly changed his tune, deciding physics was more down to earth. Nevertheless, he continued to work his way through school serving as a section cellist for the Chattanooga Symphony and Opera Orchestras. Eventually it dawned on him that experimental psychology was the scientific cat's pajamas; once again his major changed. After a frenetic four years, he received his B.A., summa cum laude, from Southern College of SDA in Collegedale, Tennessee, with a major in psychology and minors in physics, computer science, and history. After a year off, during which he continued to work as a professional, gigging musician, he came to the University of Florida as a first-year graduate student in psychobiology. It was, somehow, proper, in a universal-existentialist sense, that he should wind up specializing in psychophysiology, with its myriad of electrophysiological measures, and the constant need to build and repair electronic equipment; it was, in large part, because electronics was too difficult that he discontinued his undergraduate physics major.

Focussing on cognitive psychophysiology, an area replete with startling potential, he received his M.S. in December, 1988, and his Ph.D. in August, 1989. In July, 1989, following the why-put-off-until-tomorrow-what-you-can-do-yesterday principle, he commenced an Assistant Professorship at Loma Linda University in Loma Linda and Riverside, California.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. Keith Berg, Chairman
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Elizabeth D. Capaldi
Professor of Psychology

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Donald J. Stehouwer
Associate Professor of
Psychology

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Ira S. Fischler
Professor of Psychology

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Peter J. Lang
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1989

Dean, Graduate School

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